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MATHÉMATIQUES

SUR LA «DURETÉ AFFINE» DES POLYÈDRES

Par N. TCHETVEROUKHINE

(Présenté par S. L. Soboleff, de l'Académie, le 21. VIII. 1943)

Définition. Un polyèdre P' sera appelé *affinement dur* *, si chaque polyèdre P'_1, équivalent (1) dont les faces sont respectivement affines aux faces du polyèdre P', est sa transformation affine.

On nommera image P d'un polyèdre P' la projection de son réseau. Les points, droites et plans (éléments) du polyèdre définissent dans l'espace ses éléments incidents (en abrégé «incidences»). Il leur correspond sur le plan des images les images (projections) de ces incidences. Une partie des images de telles incidences appartient à l'image du polyèdre. Si toutes les autres images des incidences sont déterminées par l'image du polyèdre; nous disons que cette image est *complète*, et dans le cas contraire *incomplète*. Par exemple, tous les polyèdres dont les angles aux sommets sont trièdres, en particulier les polyèdres équivalents à un trièdre, à un cube ou bien à un dodécaèdre; ont toujours des images complètes [puisque chaque face d'un tel polyèdre est déterminée par les traces (arêtes) sur les deux autres faces voisines] **. Au contraire, les polyèdres dont toutes les faces sont des triangles (le nombre des faces $n>4$); en particulier les polyèdres équivalents à un octaèdre ou bien à un icosaèdre; ont toujours des images incomplètes (car ces dernières se réduisent à l'image de l'ensemble des sommets des polyèdres).

Le nombre des paramètres indépendants qui doivent être donnés sur une image pour que l'image devienne complète sera nommé *coefficient de défaut* de l'image (k).

Le coefficient de défaut d'un polyèdre peut être calculé de la manière suivante. Evaluons le nombre des paramètres p_n qu'il faut donner sur une image pour qu'elle soit complète. Ce nombre est défini par la formule

$$p_n = 3n - 4 - m_1 - 2m_2 - 3m_3 - \ldots - lm_l, \qquad (1)$$

où n est le nombre des faces du polyèdre, et $m_1, m_2, \ldots, m_l$ sont respectivement le nombre des sommets par lesquels il passe $4, 5, 6 \ldots, l+3$ arêtes. Le calcul est effectué suivant les faces du polyèdre. Ensuite déterminons le nombre des paramètres p_g déterminés par l'image du polyèdre. On aura la formule

$$p_g = 2s + s_1. \qquad (2)$$

Dans cette formule le calcul est effectué suivant les sommets du polyèdre, et on a désigné par s le nombre des sommets «indépendants» (2 paramètres) et par s_1 le nombre des sommets «semidépendants» (1 paramètre) de l'image.

* Cette terminologie m'a été proposée par le professeur D. I. Perepelkine.
** On trouvera les détails dans ce qui suit.

Les sommets «dépendants» en nombre s_2 (0 paramètres) n'entreront évidemment pas dans la formule (2). Le coefficient de défaut de l'image d'un polyèdre est évidemment égal à la différence des nombres p_u et p_g, donc

$$k = p_u - p_g. \qquad (3)$$

1) Appliquons ces formules à un hexaèdre équivalent à un cube. Nous aurons $n=6$, $m_1=m_2=\ldots=m_l=0$, $s=7$, $s_1=0$, $s_2=1$, $p_u=14$, $p_g=14$, $k=0$. L'image est complète.

2) Appliquons les mêmes formules à un octaèdre équivalent à un octaèdre régulier. Nous aurons $n=8$, $m_1=6$, $m_2=m_3=\ldots=m_l=0$, $s=6$, $s_1=s_2=0$, $p_u=14$, $p_g=12$, $k=2$. L'image est incomplète ($k=2$).

3) Considérons une pyramide à r faces. Nous aurons $n=r+1$, $m_l=0$ ($i\neq r-3$), $m_{r-3}=1$, $s=r+1$, $s_1=s_2=0$, $p_u=2\ (r+1)$, $p_g=2\ (r+1)$, $k=0$. L'image est complète.

Démontrons le théorème suivant: *Pour qu'un polyèdre P' soit affinement dur il faut et il suffit que son image soit complète.*

La nécessité de la condition. Montrons que si l'image P est incomplète, on peut construire un polyèdre P_1' dont les faces sont respectivement affines à celles de P', mais qui n'est pas affin à ce dernier. Considérons deux faces voisines ABC et ABD de l'image P du polyèdre P' et leur arête commune AB (les lettres A, B, C et D désignent les images des quatre sommets du polyèdre). Projectons tous les autres sommets du polyèdre du sommet C sur la face ABD. Les projections des sommets sur le plan ABD seront nommées *secondaires* et désignées par des petites lettres. Si toutes les projections secondaires étaient déterminées par l'image P, cette dernière serait complète comme construite par le principe de «deux traces», ayant les faces ABC et ABD comme «plan des traces» et l'arête AB pour «axe des traces» (*). Construisons sur le plan des images toutes les projections secondaires des sommets qui sont déterminées par l'image P. Soit M l'un des sommets pour lesquels la projection secondaire reste indéterminée. Choisissons cette dernière (m_1) sur la droite MC d'une manière arbitraire, mais de sorte que $(MCm_1)\neq(M'C'm')$. Après avoir choisi la projection secondaire m_1, construisons toutes les projections secondaires qui sont déterminées par l'image $(P+m_1)$. S'il reste des projections secondaires qui ne sont pas définies par cette image, on procède d'une manière analogue à la précédente en choisissant une projection n_1 sur la droite NC.

On construit ensuite les projections secondaires des sommets suivant l'image $(P+m_1+n_1)$ et ainsi de suite, jusqu'à ce que tous les sommets du polyèdre soient déterminés sur l'image au moyen des projections secondaires. Supposons que P est une projection *parallèle* du polyèdre P'. Prenons les faces $A'B'C'$ et $A'B'D'$ pour les «plans des traces», alors l'image $(P+m+n+\ldots)$ correspond au polyèdre P' et l'image $(P+m_1+n_1+\ldots)$ au polyèdre P_1'. Ce dernier comme ayant des faces respectivement affines à celles du polyèdre P' n'est évidemment pas sa transformation affine (c. q. f. d.).

La suffisance de la condition. Supposons que le polyèdre P' a une image complète P. Démontrons que chaque polyèdre P_1' dont les faces sont respectivement affines à celles du trièdre P' est une transformation affine de ce polyèdre. Appelons *polyèdre complet* Π' *du polyèdre* P' la figure, formée par tous les plans des faces du polyèdre P'; ainsi que par les lignes d'intersection de ces faces («arêtes» du polyèdre complet Π') et leurs points d'intersection («sommets» du polyèdre complet Π').

Désignons pas Π^* l'image du polyèdre complet Π'. L'image P est une partie de l'image Π ($P\subset\Pi$). Comme P est complète par hypothèse, P détermine Π. Démontrons que si l'image P est donnée; on peut construire Π en utilisant

* Si toutes les faces du polyèdre sont «linéairement indépendantes», l'image Π présente une configuration «polyédrique» (P_γ, G_π).

seulement les éléments (points; droites) qui appartiennent à l'image II. Remarquons d'abord qu'une telle construction serait facile à effectuer si en chaque sommet de l'image P on avait construit toutes les arêtes de l'image II. En effet, prenons deux faces voisines α et β de l'image P pour «plans des traces» et leur arête commune s pour «axe des traces». Supposons que l'arête s coupe l'autre arête s_1 au sommet S_1. Désignons les faces de l'arête s_1 par α_1 et β_1. Les traces de ces faces sur les plans α et β seront désignées respectivement par les lettres $(\alpha\alpha_1)$; $(\beta\alpha_1)$; $(\alpha\beta_1)$ et $(\beta\beta_1)$; et supposons ensuite que l'arête s_1 coupe l'arête s_2 au sommet S_2. Désignons les faces de l'arête s_2 par α_2 et β_2, et leurs traces («arêtes» de l'image II) sur les plans α_1 et β_1 respectivement par $(\alpha_1\alpha_2)$; $(\beta_1\alpha_2)$, $(\alpha_1\beta_2)$ et $(\beta_1\beta_2)$.

Alors la construction des traces du plan α_2 sur les «plans des traces» α et β peut être exprimée par les formules symboliques suivantes:

$$(\alpha\alpha_1)\times(\alpha_1\alpha_2)=(\alpha\alpha_1\alpha_2) \qquad (\beta\alpha_1)\times(\alpha_1\alpha_2)=(\beta\alpha_1\alpha_2)$$
$$(\alpha\beta_1)\times(\beta_1\alpha_2)=(\alpha\beta_1\alpha_2) \qquad (\beta\beta_1)\times(\beta_1\alpha_2)=(\beta\beta_1\alpha_2)$$
$$(\alpha\alpha_1\alpha_2)(\alpha\beta_1\alpha_2)=(\alpha\alpha_2) \qquad (\beta\alpha_1\alpha_2)(\beta\beta_1\alpha_2)=(\beta\alpha_2)$$

et d'une manière analogue pour le plan β_2. Ainsi, en étendant ce procédé suivant toutes les arêtes du réseau P, nous construirons les traces de toutes les faces sur les plans α et β; donc nous construirons toute l'image II.

Revenons à l'image P. Supposons qu'à partir de l'image P on peut construire (en n'utilisant que les éléments de l'image II) des nouveaux sommets et arêtes de l'image II qui n'appartiennent pas à l'image P. Supposons que l'image $P^{(1)}$ ainsi obtenue est une partie de II qui ne coïncide pas avec II; cela ne peut avoir lieu que dans le cas où l'on n'a pas construit toutes les arêtes de l'image II aux sommets de $P^{(1)}$. Menons arbitrairement par l'un des sommets de l'image $P^{(1)}$ l'arête qui manque et désignons-la par x. En continuant alors la construction des éléments de l'image II, on peut ou bien aboutir à une contradiction; ce qui signifie que l'arête x est construite et l'image $P^{(1)}$ peut être prolongée; ou bien il n'y aura pas de contradiction. Dans les deux cas nous arriverons à une certaine image $P^{(2)}$. Si $P^{(2)}$ n'est qu'une partie de l'image II; alors en répétant le même raisonnement on arrivera à une image $P^{(3)}$ et ainsi de suite. Comme résultat de ce procédé fini on obtient l'image II sans contradiction. Si, d'ailleurs, aucune des arêtes de l'image n'a été choisie arbitrairement, on a démontré ce que l'on cherchait. Dans le cas contraire l'image P est incomplète, ce qui contredit à l'hypothèse. Nous avons ainsi démontré que l'image II peut être construite à partir de l'image P en n'utilisant que les éléments appartenant à II.

Considérons maintenant le second polyèdre P_1' dont les faces sont respectivement affines aux faces du polyèdre P'. Désignons par Π_1' le polyèdre complet du polyèdre P_1', et par P_1 et Π_1 les images correspondantes.

Démontrons que les «faces» correspondantes des polyèdres complets Π' et Π_1' sont aussi affines. Nous partons de ce que les faces correspondantes des polyèdres P' et P_1' sont affines. En supposant que les images sont obtenues au moyen d'une projection parallèle, on peut conclure que les faces des images sont affines quand il est ainsi pour les faces de ce que l'on projette, et inversement. Donc, il suffit de démontrer que les «faces» correspondantes des images complètes de II et Π_1 sont affines. On peut construire l'image II à partir de P en trouvant les sommets et les arêtes du polyèdre complet (sant utiliser d'autres points et droites). D'une manière analogue, on peut obtenir l'image Π_1 à partir de P_1. Cherchons quelles sont les opérations qui donnent des nouveaux sommets et arêtes. Chaque sommet nouveau est obtenu comme point d'intersection de deux arêtes d'une face du polyèdre. Comme les faces correspondantes des images P et P_1 sont affines, les points d'intersection (sommets) des couples correspondantes d'arêtes de ces faces sont affinement correspondants. D'ailleurs, les sommets nouveaux seront des points correspondants des arêtes et forment des rapports simples égaux des sommets sur les arêtes dans les deux images

(II et Π_1). Donc; les sommets construits sont correspondants pour les faces qui passent par les arêtes définissant ces sommets. On peut construire une nouvelle arête de l'image II (respectivement Π_1) en joignant deux sommets situés sur une même face. Comme les sommets déjà construits sont affinement correspondants dans les faces des deux images, les arêtes qui les joignent seront des droites correspondantes de ces faces. On en conclut que dans le procédé de construction de nouveaux sommets et arêtes des images II et Π_1 la correspondance affine des figures situées sur les faces correspondantes sera conservée. Donc, elle sera conservée par tous les sommets et toutes les arêtes qui sont situés sur les faces correspondantes des images II et Π_1.

Soient α et β deux faces voisines de l'image II. Désignons par C et D deux sommets appartenant à leur arête commune s. Choisissons encore un sommet A sur la face α et un sommet B sur la face β. A l'image $ABCD$ il correspond l'ensemble de quatre sommets $A'B'C'D'$ du polyèdre Π'. Dans le polyèdre Π_1' il lui correspond un ensemble de 4 sommets $A_1'B_1'C_1'D_1'$. D'après le théorème de Poltke-Schwarz l'image $ABCD$ est la projection parallèle d'une figure $\overline{A}_1\overline{B}_1'\overline{C}_1'\overline{D}_1'$ semblable à la figure $A_1'B_1'C_1'D_1'$. Dans la similitude de ces figures il correspond au polyèdre Π_1' un polyèdre $\overline{\Pi}_1'$ dont les faces sont évidemment affines aux faces correspondantes du polyèdre Π'. Montrons que l'image $\overline{\Pi}_1$ coïncide avec l'image II. Les triangles ACD et $\overline{A}_1\overline{C}_1\overline{D}_1$ coïncident d'après l'hypothèse, ainsi que les triangles BCD et $\overline{B}_1\overline{C}_1\overline{D}_1$. En vertu de ce que les figures dans les faces correspondantes α et α_1 des polyèdres II et $\overline{\Pi}_1$ sont affines, ces figures coïncident. On peut dire le même en ce qui concerne les figures sur les faces β et $\overline{\beta}_1$. Toutes les autres couples des faces correspondantes des images II et $\overline{\Pi}_1$ ont des faces qui coïncident (ainsi que les sommets qui leur appartiennent) sur les plans, donc ils contiennent chacune au moins trois points coïncidents. En vertu de ce que les figures dans les faces correspondantes sont affines; ces figures coïncident aussi. Il en résulte que les images II et $\overline{\Pi}_1$ coïncident. Mais comme la projection est parallèle, cela signifie que Π' et $\overline{\Pi}_1'$ sont affins (car leurs points correspondants peuvent être déterminés par des coordonnées affinement invariantes par rapport aux tétraèdres $A'B'C'D'$ et $\overline{A}_1'\overline{B}_1'\overline{C}_1'\overline{D}_1'$).

Comme les polyèdres complets Π' et $\overline{\Pi}_1'$ sont affins; il en résulte que les polyèdres complets Π' et Π_1' sont aussi affins. Et enfin, les parties correspondantes des polyèdrés complets — les polyèdres P' et P_1' — sont encore affins, ce qu'il fallait démontrer.

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LITTÉRATURE CITÉE

[1] L. Lusternik, Corps convexes, 1941. [2] E Müller u. E. Krupp, Die linearen Abbildungen, Leipzig u. Wien, 1923.

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TECHNICAL PHYSICS

QUANTITATIVE ANALYSIS FROM ABSORPTION SPECTRA BY THE METHOD OF PHOTOMETRIC INTERPOLATION

By V. K. PROKOFIEV and O. N. SETKINA

(Communicated by S. I. Wawilow, Member of the Academy, 30. VIII. 1943)

In carrying on quantitative analysis with absorption spectra use is customarily made of a special photometer with the determination of wave-lengths of the regions of equal intensity in the spectrum of the solution and the solvent. Also the method of photographic photometry is employed with the application of blackening marks and the photometric measurement by means of a microphotometer which may or may not be provided with a self-recording device. These methods imply the use of an optical separator and a microphotometer besides the spectral apparatus. For industrial work, however, simple and more easily available appliances are desirable. In this respect the method of photometric interpolation with step-weakener suggests itself a as more convenient procedure, which has, moreover, been extensively used, and with good result, in the quantitative spectrum analysis of metals and alloys (1). The study of this method as made by one of us (2), has shown that with a correctly calibrated step-weakener the visual photometric estimate gives the same values of relative intensities with the method of photographic photometry when characteristic photoplate curves are built up. What is described below is the use of this method for quantitative analysis from absorption spectra in conjunction with the method of displaced spectra; as proposed by Müller (3).

We suppose the law of Lambert-Baire to be valid, that is in the usual notations

$$\log \frac{I_0}{I} = kcd. \qquad (1)$$

For taking photographs of the absorption spectrum we choose a source of light with not very great number of spectral lines in the region we are interested in (for instance; a quartz mercury arc; an argon tube or an a. c. arc between metal electrodes of a suitable alloy). The photographic procedure is carried out in two stages; the step-weakener is placed in front of the spectrograph slit.

1. The spectrum of the source is photographed through the solvent with a certain duration of exposure; and in this way, spectrum 1 is obtained.

2. The plate-holder of the spectrograph is shifted 0.2—0.3 mm toward the dispersion and in the vertical direction, and photographs of spectrum 2 of the same source are taken across a layer of the investigated solution of concentration c aud thickness d. The length of the exposure may be the same as in the case of spectrum 1; or else it may be increased in order to obtain spectral lines in a region of strong absorption.

In that way we get two spectra displaced with respect to each other; spectrum 2 lying in between the steps of spectrum 1. For photometric measurement two spectral lines are selected. One, λ_2, within the region of absorption, the other; λ_1,

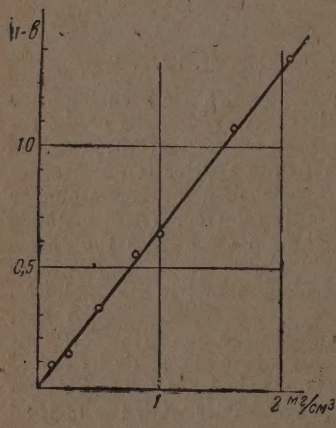
outside this region. Each is doubled on the photograph, and the visual photometry of these pairs is carried out as follows:

1. The photometry of the pair λ_1 lying outside the absorption region, gives us the value of $a = \log \frac{I_1'}{I_1}$, where I_1 and I_1' are intensities of the line λ_1 in spectrum 1 and 2, respectively. So the value of a indicates the intensity difference between the two spectra.

2. In a similar way the photometry of the pair λ_2 lying inside the absorption region secures the value $b = \log \frac{I_2'}{I_2}$, where I_2 and I_2' are intensities of the line λ_2 in spectrum 1 and spectrum 2, respectively.

We derive from this the difference $a - b = \log \frac{I_1'}{I_2'} \cdot \frac{I_2}{I_1}$.

It may be easily seen that the quantity $I_2 \cdot \frac{I_1'}{I_1}$ gives the intensity of the light of wave-length λ_2 falling upon the solution when the spectrum 2 is photographed, and the quantity I_2', the intensity of the light passing through the solution. Thus, the quantity $a - b$ represents the left-hand side of the relation (1) and we have



$$kcd = a - b. \qquad (2)$$

The difference in the exposure time of the two spectra is allowed for by photometring the pair λ_1. By means of the relation (2) the following quantitative problems can be solved.

1. The absorption coefficient k can be determined from only one photograph, if the concentration and the thickness of the layer are known, viz. $k = \frac{a-b}{cd}$. But a more accurate estimate is obtained if several photographs are taken for different thicknesses d of the solution layer with a known and invariable concentration c, and on the basis of these data the relation (2) is plotted. The result is a straight line and the tangent of its angle of slope gives the value of kc.

2. If the concentration is to be determined while the value of k is known; this may be done from a single photograph without varying the thickness d; viz. $c = \frac{a-b}{kd}$. Yet, the better method is to take several spectra for different thicknesses. We may then choose the most suitable spectrum for photometry and refine the estimate by measuring more than one spectrum. If the value of k is unknown; the concentration must be determined from a calibrated curve built on data obtained with specially prepared samples of different concentration, but invariable thickness d.

The accuracy of measurement and the construction of a graph are determined by that $a - b = 0$ for $c = 0$ or $d = 0$, in other words, the right line of the calibrated curve should run through the origin.

In Table 1 some data for the construction of a calibrated curve are given by way of example, and in the figure we have such a curve plotted for benzene, the measurement referring to the line $\lambda_2 = 2536$ Å. The results of an analysis of some alcohol solutions of benzene carried out with this plot, are presented in Table 2.

Tables 1 and 2 illustrate the reproducibility of individual measurements and the accuracy of concentration estimates. With regard to the latter it may be remarked that the method of photometric interpolation offers here a greater advantage than in analysing alloys.

Table 1

c mg/cm³	$a-b$ 1	2	3	4	Mean
0.1	0.08	0.09	0.10	0.08	0.09
0.25	0.11	0.13	0.14	0.16	0.13
0.50	0.33	0.33	0.32	0.33	0.33
0.80	0.56	0.57	0.53	0.58	0.56
1.00	0.64	0.65	0.64	0.64	0.64
1.60	1.09	1.10	1.02	1.10	1.08
2.05	1.35	1.34	1.40	1.35	1.36

Table 2

c in mg/cm³ Given	Measured
0.11	0.11
0.173	0.18
0.19	0.18
0.30	0.30
0.48	0.49
0.613	0.62
1.12	1.11
1.76	1.74

In fact; the relative error involved in the concentration estimates may be evaluated from the relation (2) as

$$\frac{\delta c}{c} = \frac{\delta (a-b)}{a-b}. \qquad (3)$$

In the case of alloys the concentration enters under the logarithm sign ($\log I = b \log c + \log a$), and we have therefore

$$\frac{\delta c}{c} = 2.3\, \delta (\log I). \qquad (3')$$

In formula (3) the relative error in the concentration depends upon the relative error of photometry, and this is the smaller; the larger the value of $(a-b)$. Now the latter may be increased by correspondingly selecting the layer thickness d. With metals the case is different. Here, as follows from (3′), the relative error of the concentration estimate is determined by the absolute error of the photometric measurement δ (log I).

In the case of spectra rich in lines, the displacement of the photographic plate in the direction of dispersion is not to be carried out, for the lines of the spectrum would be superimposed one upon another. But then we can proceed in the following way. Spectrum 1 is photographed through the step-weakener. The step-weakener is then removed and a narrow diaphragm placed before the spectrograph slit. By moving the plate-holder in the vertical direction the narrow spectrum of the solution photographed through the diaphragm is brought in close vicinity to spectrum 1. The photometric measurement is conducted as before, except that now spectrum 2 has virtually only one step instead of the several steps, that permitted us under the first scheme to refine the results obtained.

In either case the very important advantage of the method is that in every pair of lines the measurement is carried out for a single wave-length; and so the dependence of the contrast value of the plate on the wave-length has no influence here. To control the intensities of spectra we may choose the line λ_1, anywhere in the spectrum; its distance from the line λ_2 being subject here to no restrictions.

It may be noted that in case a different exposure is used in photographing the spectra 1 and 2, we have to introduce the constant of Schwartzschield. If, however, the calibration and the subsequent determinations are made throughout at definite exposures; this constant will enter into the calibration curve or into the preliminarily determined value of k, and will not affect the results.

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ELECTRICAL ENGINEERING

STABILITY OF OPERATION AND TRANSIENT PROCESSES IN THE LEONARD SYSTEM

By V. P. NIKITIN, Member of the Academy, and N. P. KUNITZKI

When the inductance of the main circuit is taken into account, the equations of transient processes have the following form: for the velocity n of the mechanism's motor

$$\frac{d^2n}{dt^2}+\left(\frac{1}{T}+\frac{375D}{GD^2}\right)\frac{dn}{dt}+\frac{375Sn}{TGD^2}=$$

$$=\frac{375\{(S-D)[n_{0y}-(n_{0y}-n_{00})e^{-t/T_f}]-A\}}{TGD^2}, \qquad (1)$$

for the current i of the motor

$$\frac{d^2i}{dt^2}+\left(\frac{1}{T}+\frac{375D}{GD^2}\right)\frac{di}{dt}+\frac{375Si}{TGD^2}=$$

$$=\frac{375(S-D)}{TGD^2\cdot k\Phi}\{A+D[n_{0y}-(n_{0y}-n_{00})e^{-t/T_f}]\}+\frac{c\Phi(n_{0y}-n_{00})e^{-t/T_f}}{T_fL} \qquad (2)$$

where T is the time constant of the main circuit; D is the tangent of the angle of the characteristic of the mechanism: $M_s=f(n)$; $S=\frac{kc\Phi^2}{R}+D$ is the coefficient of stability; Φ is the magnetic flux of the mechanism's motor; R and L are ohmic resistance and inductance of the main circuit, respectively; GD^2 is the torque of the drive; T_f is the time constant of the excitation circuit; A is the moment of resistance of the mechanism for $n=0$; $n_{00}=\frac{e_{g0}}{c\Phi}$ and $n_{0y}=\frac{e_{gy}}{c\Phi}$ are the rotation numbers of the ideal idle run of the motor, corresponding to its initial emf e_{g0} and to the ultimate emf e_{gy} of the generator,

As $T_f>0$, and the roots of the characteristic equation of differential equations for the transient process in Leonard's system are the same as in the case of the transient process in a shunt motor at a constant voltage U on its armature, the conditions for stability and for the generation of oscillations in the system of Leonard are identical with those in a shunt motor at $U=\text{const}$ [1].

By solving equations (1) and (2) we obtain the equations by means of which the oscillatory process may be computed:

$$\Delta n=n-n_{y2}=e^{\beta t}\Delta n_m\sin(\omega t+\varphi_n)+\frac{375(S-D)(n_{0y}-n_{00})T_fe^{-t/T_f}}{Q} \qquad (3)$$

where

$$Q=GD^2+375DT-\frac{TGD^2}{T_f}-375ST_f,$$

$$\Delta n_m = \sqrt{\left[\Delta n_y - \frac{375\,(S-D)\,(n_{0y}-n_{00})\,T_f}{Q}\right]^2 + \left[\frac{375\,(\Delta M_y - D\Delta n_y)\,T_f}{GD^2\omega} - \frac{\beta\Delta n_y}{\omega} + \frac{375\,(n_{0y}-n_{00})\,(S-D)\,(T_f\beta+1)}{\omega Q}\right]^2}$$

$$\operatorname{tg}\varphi_n = \frac{\Delta n_y - \dfrac{375\,(S-D)\,(n_{0y}-n_{00})\,T_f}{Q}}{\dfrac{375\,(\Delta M_y - D\Delta n_y)}{\omega GD^2} - \dfrac{\beta\Delta n_y}{\omega} + \dfrac{375\,(n_{0y}-n_{00})\,(S-D)\,(T_f\beta+1)}{\omega Q}};$$

$$\Delta i = i - i_{y2} = e^{\beta t}\Delta i_m \sin(\omega t + \varphi_i) + \frac{(n_{0y}-n_{00})\,(S-D)\,(375\,DT_f - GD^2)\,e^{-t/T_f}}{k\Phi Q}, \quad (4)$$

where

$$\Delta i_m = \sqrt{\left[\frac{e_{g0} - i_1 R - c\Phi n_1}{L\omega} + \frac{(n_{0y}-n_{00})\,(T_f\beta+1)\,(S-D)\,(375\,DT_f - GD^2)}{\omega k\Phi Q T_f}\right]^2 + \left[\Delta i_y - \frac{(n_{0y}-n_{00})\,(S-D)\,(375\,DT_f - GD^2)}{k\Phi Q}\right]^2}$$

and

$$\operatorname{tg}\varphi_i = \frac{\Delta i_y - \dfrac{(n_{0y}-n_{00})\,(S-D)\,(375\,DT_f - GD^2)}{k\Phi Q}}{\dfrac{(n_{0y}-n_{00})\,(T_f\beta+1)\,(S-D)\,(375\,DT_f - GD^2)}{\omega\Phi k Q T_f} - \dfrac{\beta\Delta i_y}{\omega} + \dfrac{e_{g1} - i_1 R - c\Phi n_1}{L\omega}}.$$

Here

$$\beta = -\frac{1}{2}\left(\frac{1}{T} + \frac{375\,D}{GD^2}\right);$$

$$\omega = \sqrt{\frac{375\,S}{TGD^2} - \frac{1}{4}\left(\frac{1}{T} + \frac{375\,D}{GD^2}\right)^2}.$$

If the transient process begins in an unsettled state, then

$$\Delta M_y = M_1 - M_{y2}; \quad \Delta n_y = n_1 - n_{y2}; \quad \Delta i_y = i_1 - i_{y2},$$

where M_1, n_1, i, and e_{g1} are the initial values of the torque, velocity and current of the motor, and of emf of the generator, respectively.

On the other hand, if there is a settled state at the beginning of the transient process, we have

$$\Delta M_y = M_{y1} - M_{y2}; \quad \Delta n_y = n_{y1} - n_{y2}; \quad \Delta i_y = i_{y1} - i_{y2},$$

where M_{y1}, n_{y1}, i_{y1} are the values at the initial equilibrium, and M_{y2}, n_{y2}, i_{y2}, are the respective values at the new equilibrium.

The equations for the calculation of the aperiodic process are of the same form as in the case of oscillatory process, except that the circular functions must be replaced by hyperbolical, and $\gamma = \omega/j$ substituted for ω, taking, moreover, into consideration that $\omega^2 = -\gamma^2$.

From equations (3) and (4) it follows that the transient oscillatory process in Leonard's system consists of the oscillatory portion with amplitude Δn_m (resp. Δi_m) and the aperiodic portion with time constant T_f.

Thus, if with a shunt motor working at $U = \text{const}$ the oscillations — in the case of an oscillatory transient process — take place near the horizontal axis corresponding to the ultimate settled value, they proceed in the Leonard system near the axis presenting the curve of the aperiodic portion of the process. The transient processes go on the more rapidly, the smaller T and GD^2 and the larger the positive value of D. Their speed also increases with decreasing T_f.

For the transition from one voltage of the generator to another, that is, in the case of a change in the excitation current, we have $\Delta M_y = D\Delta n_y$, and the equations (3) and (4) become simpler. Putting in them $n_{y1} = 0$, $M_{y1} = A$, $\Delta n_y = -n_{y2}$, $\Delta M_y = -Dn_{y2}$, we easily get the equations for the starting pro-

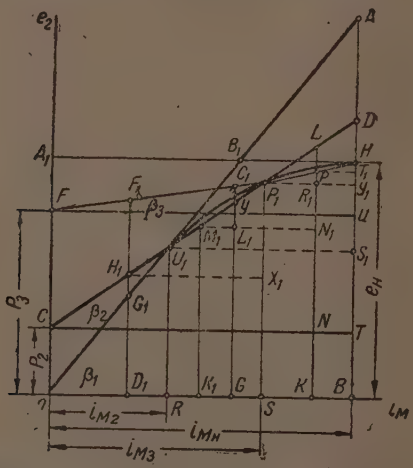
cess of the motor. The above equations may as well be applied to the braking and reversal processes; both in the case of a positive and negative static moment.

Setting arbitrarily different values for the drive constants GD^2; L; R; S, D; we can investigate the influence of these constants upon the peak of the current and the time in which it is obtained; as well as upon the amplitudes and initial phases of the current and velocity.

Let us now take the saturation of the generator into account. The characteristic of the no-load run of the generator does not lend itself easily to accurate expression by an equation, and even if an approximate equation is used; great difficulties are still experienced connected with the integration of differential equations.

On the other hand; the use of grapho-analytical methods for an approximate integration of differential equations only solves the problems relative to a particular case; but no general solution can be obtained in this way.

It seems therefore expedient in calculating transient processes with allowance for saturation to replace the characteristic of the generator by several



linear segments within which the curve can be considered a straight line with sufficient degree of accuracy.

Then the emf of the generator for an i-th segment will be $e_g = p_i + i_f \operatorname{tg} \beta_i = p_i + i_f \; m_i$, where $m_i = \operatorname{tg} \; \beta_i$ (see figure), and i_f is the excitation current of the generator.

The differential equations for the process within an i-th segment will have the form:

$$\frac{d^2n}{dt^2} + \left(\frac{1}{T} + \frac{375\,D}{GD^2}\right)\frac{dn}{dt} + \frac{375\,Sn}{TGD^2} =$$

$$= \frac{375\,k\Phi}{LGD^2}\left[p_i + m_i i_{fy} - m_i\,(i_{fy} - i_{foi})\,e^{-t/T_{fi}}\right] - \frac{375\,AR}{LGD^2} \qquad (5)$$

$$\frac{d^2i}{dt^2} + \left(\frac{1}{T} + \frac{375\,D}{GD^2}\right)\frac{di}{dt} + \frac{375\,Si}{TGD^2} =$$

$$= \frac{375}{GD^2L}\left\{D\left[p_i + m_i i_{fy} - m_i\,(i_{fy} - i_{foi})\,e^{-t/T_{fi}}\right] + Ac\Phi\right\} +$$

$$+ \frac{m_i\,(i_{fy} - i_{foi})}{LT_{fi}}\,e^{-t/T_{fi}}; \qquad (6)$$

where i_{fy} is the steady current of excitation; i_{foi}, the excitation current at the beginning of the transient process if the latter is confined within the segment

i, or, to put it differently; at the beginning of that part of the transient process which takes place within the limits of the segment i; that is; at the beginning of segment i if the process continues through this segment after having started in the previous one $i-1$.

Passing in equations (5) and (6) to the velocities of the ideal no-load run we obtain:

$$\frac{d^2n}{dt^2}+\left(\frac{1}{T}+\frac{375\,D}{GD^2}\right)\frac{dn}{dt}+\frac{375\,Sn}{TGD^2}=$$

$$=\frac{375\,\{(S-D)\,[\mu n_{oy}-(\mu n_{oy}-n_{oi})\,e^{-t/T_{fi}}]-A\}}{TGD^2} \qquad (7)$$

$$\frac{d^2i}{dt^2}+\left(\frac{1}{T}+\frac{375\,D}{GD^2}\right)\frac{di}{dt}+\frac{375\,Si}{TGD^2}=$$

$$=\frac{375\,(S-D)}{TGD^2k\Phi}\{D\,[\mu n_{oy}-(\mu n_{oy}-n_{oi})\,e^{-t/T_{fi}}]+A\}+\frac{c\Phi\,(\mu n_{oy}-n_{oi})}{LT_{fi}}\,e^{-t/T_{fi}} \qquad (8)$$

where μ is the ratio between the ordinate cut off by the straight line replacing the i-th segment on the vertical drawn from the end of the ultimate excitation current i_{fy}, and the ultimate settled emf (e_{gy}) of the generator.

If, for instance, the initial excitation current $i_{fo}=OK_1$ lies within the second segment and the ultimate current $i_{fy}=OK$ within the third; then

$$\mu=\frac{LK}{PK}=\frac{LK}{e_{gy}}.$$

Supposing, on the other hand, that $i_{fy}=OG$ lies within the segment (second) in which the transient process has started, we shall have $\mu=1$.

If the process going on in the segment considered (i) has started in the segment just preceding it, the quantity n_{oi} in the expressions (7) and (8) is understood to mean the rotation number corresponding to the beginning of the segment i.

But if the process begins in the very segment i; the n_{oi} is the rotation number corresponding to the start of the transient process.

When the calculation is made for a saturated generator; the equations (3) and (4) for not saturated may still be used, but the values of T_{fi} have then to correspond to the considered segment of the characteristic, and while for those segments within which the process comes to an end, the equation for the saturated generator differs in nothing from that of the not saturated, the allowance for the saturation, in the case of the segments within which the process starts or through which it continues without expiring there; is reduced to the introduction, before the ultimate rotation number n_{oy}, of a coefficient μ determined for the ultimate excitation current.

For those segments, however, through which the process continues; we should mean by n_{oi} the number of rotations at the beginning of the segment.

This allowance for the saturation of the generator relates also to the starting and braking processes of the motor. In the case of braking, for instance, the taking account of the saturation within all segments but the last reduces to the introduction, before the ultimate rotation number n_{oy}, of the coefficient μ; which is the ratio between the intercept cut off on the vertical arising from the ultimate excitation current i_{fy} by the straight line approximating the characteristic within the segment in which the transient process goes on, and the ultimate emf e_{go}.

Thus, when the braking changes the velocity determined by the excitation current $i_{fo}=OB$ into that corresponding to $i_{fy}=OD_1$ ($e_{gy}=G_1D_1$), we have to make the following substitutions in the equation for the not saturated current: for the portion of the process running in the third segment, n_{oy} is replaced by the quantity $\mu_1 n_{oy}$ where $\mu_1=\frac{D_1F_1}{D_1G_1}$; for the portion in the second segment the quantity $\mu_2 n_{oy}$, where $\mu_2=\frac{D_1H_1}{D_1G_1}$, comes in place of n_{oy}; while the initial values of M_1; n_1 and i_1

are substituted, respectively, by the values corresponding to the beginning of the second segment, that is, to point S; finally, for the portion of the process running within the first segment the initial values of M_1, n_1 and i_1 are understood to mean those values of the same quantities that correspond to point R.

Substituting in (1) and (2) $T = 0$, we obtain the equations of transient processes without allowance for the inductance of the main circuit. To take account of the saturation in this case we must proceed precisely in the same way, as we do in allowing for the inductance.

By means of the established equations the curves of transient processes can be built and the peaks of the current determined either with or without making allowance for the saturation of the generator.

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ELECTRICAL ENGINEERING

ANALYSIS OF TRANSIENTS IN A BRUSH-SHIFTING A. C. MACHINE

By P. A. SVIRIDENKO

(Communicated by K. I. Shenfer, Member of the Academy, 20. IX. 1943)

Up to the present no well developed method is available for analysing the transient processes of a collector machine*. The purpose of this work has been to derive the main differential equations in the operator form for the theoretical study of transients (and stationary) in a brush-shifting a. c. machine under different regimes of operation.

The annexed figure represents an out-lay of such a machine with feeding from the rotor side.

The speed and the power factor of this machine is controlled by turning the brushes on the collector with which the secondary winding of the rotor is connected.

Let us write the voltage equations for the rotor windings

$$\left.\begin{aligned} p\psi_a + R_1 i_a &= \varphi_a \\ p\psi_b + R_1 i_b &= \varphi_b \\ p\psi_c + R_1 i_c &= \varphi_c \end{aligned}\right\} \qquad (1)$$

where $\psi_{a,b,c}$, $i_{a,b,c}$ and $\varphi_{a,b,c}$ are flux linkage, current and voltage of the phase a, b and c, respectively, $p = \frac{d}{dt}$ is the differential operator.

The voltage equations of the secondary circuit (the stator winding and the secondary winding of the rotor between the brushes) are

$$\left.\begin{aligned} p\psi_1 + R_2 i_1 &= -(p\Phi_1 + r i_1) \\ p\psi_2 + R_2 i_2 &= -(p\Phi_2 + r i_2) \\ p\psi_3 + R_2 i_3 &= -(p\Phi_3 + r i_3) \end{aligned}\right\} \qquad (2)$$

Here $\psi_{1,2,3}$, $\Phi_{1,2,3}$, $i_{1,2,3}$ are flux linkages and currents of the 1st, 2nd and 3rd phase of the stator winding and the secondary winding of the rotor.

Let us perform linear transformations on voltages, currents and linkages in the system of α, β and 0 components.

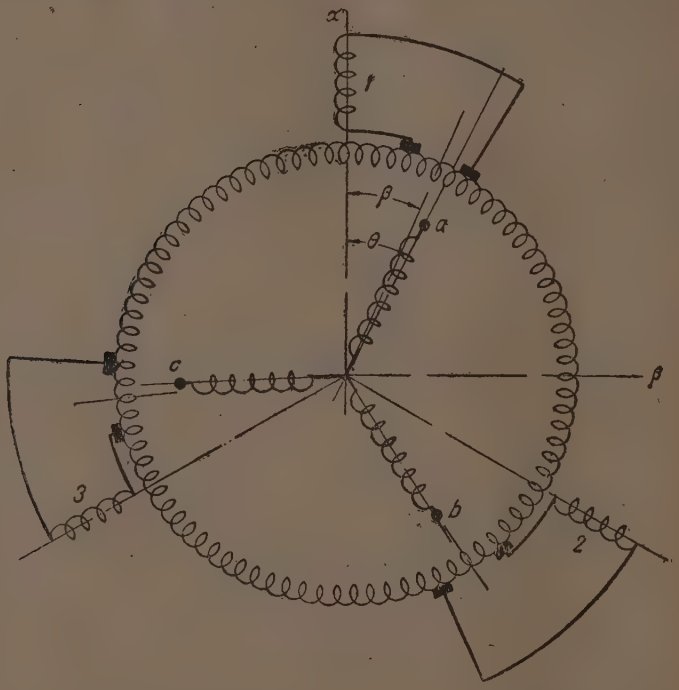
Such a transformation has been used in the case of synchronous and asynchronous machines ([1,2]).

On the figure the orthogonal coordinates α and β are immovable in relation to the stator. As a result of the transformation with respect to α and β components, the three-phase machine is reduced to a two-phase machine, the win-

* In the latest papers by American authors ([3,4]) only stationary regimes of operation are discussed.

dings of which are shifted relative to each other by 90°. Owing to this, there is no mutual induction between the stator (or rotor) windings. To the α and β components the current of zero sequence component is also added, equal in magnitude to one third of the zero-point current.

These transformations are intended to give linear differential equations with constant coefficients for the constant speed of the rotor.



The real quantities of the three-phase machine are expressed through α, β and 0 components (for the rotor).

$$\left.\begin{aligned} i_a &= I_\alpha \cos\theta + I_\beta \sin\theta + I_0 \\ i_b &= I_\alpha \cos(\theta+120) + I_\beta \sin(\theta+120) + I_0 \\ i_c &= I_\alpha \cos(\theta-120) + I \sin(\theta-120) + I_0 \end{aligned}\right\} \qquad (3)$$

ψ_a, ψ_b, ψ_c, φ_a, φ_b, φ_c are expressed through their respective components Ψ_α, Ψ_β, Ψ_0; φ_α, φ_β; φ_0 by analogy with (3).

For the secondary circuit these relations (for the stator) are:

$$\left.\begin{aligned} i_1 &= i_\alpha + i_0 \\ i_2 &= -0.5\, i_\alpha + 0.5\sqrt{3}\, i_\beta + i_0 \\ i_3 &= -0.5\, i_\alpha - 0.5\sqrt{3}\, i_\beta + i_0 \end{aligned}\right\}. \qquad (4)$$

Correspondingly, the flux linkages of the stator ψ_1, ψ_2, ψ_3 are expressed by ψ_α, ψ_β, ψ_0.

For the flux linkages of the secondary winding of the rotor (between the brushes) we have

$$\left.\begin{aligned}\Phi_1 &= \Phi_\alpha \cos\beta + \Phi_\beta \sin\beta + \Phi_0\\ \Phi_2 &= \Phi_\alpha \cos(\beta+120) + \Phi_\beta \sin(\beta+120) + \Phi_0\\ \Phi_3 &= \Phi_\alpha \cos(\beta-120) + \Phi_\beta \sin(\beta-120) + \Phi_0\end{aligned}\right\} \qquad (4')$$

The inverse transformations are obtained by solving the equations (3); (4) and (4') with respect to α, β and 0 components.

For the rotor

$$\left.\begin{aligned}I_\alpha &= \frac{2}{3}[i_a \cos\vartheta + i_b \cos(\vartheta+120) + i_c \cos(\vartheta-120)]\\ I_\beta &= \frac{2}{3}[i_a \sin\vartheta + i_b \sin(\vartheta+120) + i_c \sin(\vartheta-120)]\\ I_0 &= \frac{1}{3}[i_a + i_b + i_c]\end{aligned}\right\} \qquad (5)$$

For the stator

$$\left.\begin{aligned}i_\alpha &= \frac{2}{3}[i_1 - 0.5(i_2 + i_3)]\\ i_\beta &= \frac{\sqrt{3}}{3}(i_2 - i_3)\end{aligned}\right\} \qquad (6)$$

For the secondary winding of the rotor

$$\left.\begin{aligned}\Phi_\alpha &= \frac{2}{3}[\Phi_1 \cos\beta + \Phi_2 \cos(\beta+120) + \Phi_3 \cos(\beta-120)]\\ \Phi_\beta &= \frac{2}{3}[\Phi_1 \sin\beta + \Phi_2 \sin(\beta+120) + \Phi_3 \sin(\beta-120)]\end{aligned}\right\} \qquad (6')$$

If now in the differential quotients of the flux linkages $p\Psi_\alpha$, $p\psi_\alpha$ and $p\Phi_\alpha$ by time $p\psi_{a,b,c}$ and $p\psi_{1,2,3}$ found from the equations (1) and (2) are substituted, we obtain the fundamental equations for a two-phase machine with axes α and β.

For the rotor

$$\left.\begin{aligned}v_\alpha &= p\Psi_\alpha + R_1 I_\alpha + \Psi^\beta [p\vartheta]\\ v_\beta &= p\Psi_\beta + R_1 I_\beta - \Psi_\alpha [p\vartheta]\\ v_0 &= p\Psi_0 + R_1 I_0\end{aligned}\right\} \qquad (7)$$

For the secondary circuit

$$\left.\begin{aligned}p[\psi_\alpha + \Phi_\alpha \cos\beta + \Phi_\beta \sin\beta] + (R_2 + r) i_\alpha &= 0\\ p[\psi_\beta + \Phi_\beta \cos\beta - \Phi_\alpha \sin\beta] + (R_2 + r) i_\beta &= 0\\ p[\psi_0 + \Phi_0] + (R_2 + r) &= 0\end{aligned}\right\} \qquad (8)$$

From these equations the flux linkages must be eliminated. To do this we have to express them by means of parameters (coefficients of self and mutual induction) and α, β, 0 components of the machine currents.

The flux linkage of the phase a of the rotor and phase 1 of the stator can be represented in the form

$$\begin{aligned}\psi_a = Li_a + M_r(i_b + i_c) + M_{rs}[i_1 \cos\vartheta + i_2 \cos(\vartheta-120) + i_3 \cos(\vartheta+120)] +\\ + M_{rg}[i_1 \cos(\vartheta-\beta) + i_2 \cos(\vartheta-\beta-120) + i_3 \cos(\vartheta-\beta+120)]\end{aligned} \qquad (9)$$

where L is the self-induction of one rotor phase; M_r, the mutual induction between the rotor phases; M_{rs}, the maximum value of self-induction between one rotor phase and one stator phase; M_{rg}, the same between one rotor phase and one phase of the secondary winding of the rotor.

The flux linkage of the first phase of the stator is

$$\psi_1 = li_1 + M_s(i_2+i_3) + M_{rs}[i_a\cos\theta + i_b\cos(\theta+120) + i_c\cos(\theta-120)] + \\ + M_{sg}[i_1\cos\beta + i_2\cos(\beta+120) + i_3\cos(\beta-120)]. \quad (10)$$

Here l is self-induction of a stator phase; M_s, the mutual induction between stator phases; M_{sg}, the maximum value of mutual induction between one stator phase and one phase of the secondary winding of the rotor.

The flux linkage of the secondary winding of the rotor is

$$\Phi_1 = l_g i_1 + M_g(i_2+i_3) + M_{rg}[i_a\cos(\theta-\beta) + i_b\cos(\theta-\beta+120) + \\ + i_c\cos(\theta-\beta-120)] + M_{sg}[i_1\cos\beta + i_2\cos(\beta+120) + i_3\cos(\beta-120)]. \quad (11)$$

Substituting in (9), (10) and (11) ψ_a, ψ_1 and Φ_1, i_a, i_b, i_c, i_1, i_2 and i_3 with their components, we get, after a series of transformations, the requisite equations for α, β and 0 components of flux linkages and α, β and 0 components of currents.

For the rotor

$$\left.\begin{aligned} \Psi_\alpha &= (L-M_r)I_\alpha + (1.5M_{rs} + 1.5M_{rg}\cos\beta)i_\alpha - 1.5M_{rg}\sin\beta\cdot i_\beta \\ \Psi_\beta &= (L-M_r)I_\beta + (1.5M_{rs} + 1.5M_{rg}\cos\beta)i_\beta + 1.5M_{rg}\sin\beta\cdot i_\alpha \\ \Psi_0 &= (L+2M_r)I_0 \end{aligned}\right\} \quad (12)$$

For the winding of the stator

$$\left.\begin{aligned} \psi_\alpha &= (l-M_s+1.5M_{sg}\cos\beta)i_\alpha - 1.5M_{sg}\sin\beta i_\beta + 1.5M_{rs}I_\alpha \\ \psi_\beta &= (l-M_s+1.5M_{sg}\cos\beta)i_\beta + 1.5M_{sg}\sin\beta i_\alpha + 1.5M_{rs}I_\beta \end{aligned}\right\} \quad (13)$$

For the secondary winding of the rotor

$$\left.\begin{aligned} \Phi_\alpha &= [(l_g-M_g)\cos\beta + 1.5M_{sg}]i_\alpha - (l_g-M_g)\sin\beta i_\beta + 1.5M_{rg}I_\alpha \\ \Phi_\beta &= [(l_g-M_g)\cos\beta - 1.5M_{sg}]i_\beta + (l_g-M_g)\sin\beta i_\alpha + 1.5M_{rg}I_\beta \end{aligned}\right\} \quad (14)$$

The substitution of (12), (13) and (14) in (7) and (8) gives the fundamental differential equation of a three-phase collector shunt machine

$$\left.\begin{aligned} [R_1 + L_0 p]I_\alpha + L_0(p\theta)I_\beta + [M_0 p + M_1(p\theta)]i_\alpha + [M_0(p\theta) - M_1 p]i_\beta &= \nu_\alpha \\ -L_0(p\theta)I_\alpha + [R_1 + L_0 p]I_\beta - [M_0(p\theta) - M_1 p]i_\alpha + [M_0 p + M_1(p\theta)]i_\beta &= \nu_\beta \\ M_0 pI_\alpha + M_1 pI_\beta + [(R_2+r) + (l_0 + l_{g0} + M_2)p]i_\alpha + 0 &= 0 \\ -M_1 pI_\alpha + M_0 pI_\beta + 0 + [(R_2+r) + (l_0 + l_{g0} + M_2)p]i_\beta &= 0 \\ (L+2M_r)pI_0 + R_1 I_0 &= \nu_0 \end{aligned}\right\} \quad (15)$$

The notations introduced here are

$$L_0 = (L-M_r)$$
$$M_0 = 1.5(M_{rs} + M_{rg}\cos\beta)$$
$$M_1 = 1.5M_{rg}\sin\beta$$
$$l_0 = (l-M_s)$$
$$l_{g0} = (l_g - M_g)$$
$$M_2 = 3M_{sg}\cos\beta$$

Starting from the equation

$$T = \sum i_r i_s \frac{d}{d\theta} M_{rs},$$

it may be proved that the equation for the torque of a collector machine has the following form:

$$T = -1.5M(I_\alpha i_\beta + I_\beta i_\alpha). \quad (16)$$

The equations (15) and (16) completely define the stationary and transient regimes of a three-phase collector machine.

In many cases of transient processes the speed of the rotor may be regarded as constant $[p\theta] = \omega_r$. Under this condition the equations (15) and (16) are linear differential equations with constant coefficients. Their solution gives the currents and the torque in the operator form. Using the well-known methods of the operational calculus (the expansion theorem), the variation of the currents and the torque with time can easily be determined.

In order to take into account the change of the rotation velocity in the case of transient processes, it is necessary to apply special solutions of the equations (15) and (16).

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PHYSICAL CHEMISTRY

NATURE OF THE OXIDE FILM OF Fe-Cr-Al SOLID SOLUTION

By I. I. KORNILOV and I. I. SIDORISHIN

(Communicated by V. G. Chlopin, Member of the Academy, 28. VIII. 1943)

The different nature of oxidation of ternary Fe-Cr-Al alloys at moderate and high temperatures has been demonstrated by the investigation of the thermostability and of the process of oxidation of these solid solutions (1). It has been suggested also that at moderate temperatures all three metals of the system undergo simultaneous oxidation, and the result of this reaction is an isomorphous mixture of the oxides Al; Cr and Fe. As the temperature goes up, the aluminium (which is a more active metal chemically compared to Fe and Cr) is oxidized selectively at the expense of atmospheric oxygen and of the iron and chromium oxides of the oxide film.

Eventually; at high temperatures an oxide film consisting of pure alumina is formed, the concentration of aluminium in the surface layer decreases and there begins a diffusion of aluminium in the alloy (2).

In our attempt to study the nature of oxide films formed at moderate temperatures we made use of electronographic method (3-5). This method permits to compute from electronograms the lattice constants for the finest layers of oxide films on metals and oxides. The electronographic investigation was carried out in Prof. P. D. Dankov's Laboratory, Colloid-Electrochemical Institute, Academy of Sciences of the USSR.

Oxide films consisting of pure alumina have been studied by the radiographic method and its composition determined by chemical analysis.

The experiment was run with a Fe-Cr-Al alloy containing 70 per cent Fe, 25 per cent Cr and 5 per cent Al. A $1 \times 10 \times 20$ mm plate of this alloy, polished and washed, was subjected to oxidation at temperatures ranging from 400 to 1200° C for a period of 12 hours.

The oxide films that had formed on the surface of the alloy were studied electronographically by the method of electron diffraction. We thus obtained electronograms of oxide films formed at 400, 500, 600, 700, 800 and 1000° C.

The electronograms in Figs. 1a and 1b refer to oxidation at 400 and 1000° C, respectively.

On the basis of electronograms the crystalline lattice constants of the oxide films were calculated with reference to the oxidation temperature of the alloy. The computed data for lines of various intensities and the mean values of the lattice constant in Å are listed in the table under the respective temperatures.

It appears from these data that the oxide film formed during the oxidation on the surface of the Fe-Cr-Al solid solution is one of cubic system. The lattice constant of the film decreases with increasing temperature. The decrease continues more rapidly after a temperature of 800° C has been reached.

Nos. of lines	Temperature, °C				
	400	600	700	800	1000
1	8.351	8.179	8.079	8.059	7.835
2	8.356	8.166	8.081	8.046	7.818
3	8.332	8.237	8.116	8.039	7.930
4	8.303	8.156	8.069	8.058	7.934
5	8.285	8.175	8.041	8.052	7.907
6	8.388	8.260	—	8.046	7.879
Mean value in Å	8.328	8.195	8.077	8.050	7.882

What may be regarded as established by these facts is that at moderate temperatures an oxide film is formed corresponding to an isomorphous mixture of Al, Fe and Cr oxides with a cubic lattice of the spinel type ($RO \cdot R_2O_3$).

The presence of aluminium in the ternary alloy goes to decrease the content of iron and chromium oxides in an oxide film formed at high temperatures. Accordingly, the film should becomes higher in alumina, and that it actually does so is confirmed by the decrease of the lattice constant of the oxide film at high temperatures.

In the limiting case of 1000 C or more the lattice constant falls down to 7.882 Å approaching very closely the lattice constant of the γ-modification of pure alumina, which is 7.90 Å.

The fact of the lattice constant of the oxide film on the surface of an oxidized alloy decreasing with the increasing temperature of oxidation and its conformity with the enrichment of the oxide film with alumina, is indirectly confirmed by the radiographic studies of Clark and Ally (6) who examined the variation of the lattice constant of chromite ($FeO \cdot Cr_2O_3$) in relation to the concentration of alumina.

As the content of alumina in chromite grows, the lattice constant decreases from 8.344 Å down to lower values. The decrease is additive and obeys Wegard's law. From this they infer that alumina forms solid solutions with chromite.

In our case we found the lattice constant of the oxide film to diminish gradually when the oxidation temperature was increased. This accords well with the fact that at relatively low temperatures the alloys of Fe, Cr and Al form solid solutions of oxides with the spinel type of crystalline lattice. When the temperature increases, so does also the content of alumina in the oxide film with the result that the lattice constant of the latter is diminished (see table).

Of the two curves in Fig. 2 one brings out the variation of the lattice constant of the oxide film as a function of the oxidation temperature (according to our data); and the other, the variation of the chromite lattice constant as a function of the alumina content (according to Clark and Ally). These curves though different in character, both show that when an isomorphous mixture of the spinel type is enriched with alumina, the lattice constants decrease and at the limit come down to the value corresponding to pure alumina.

At temperatures above 1000° C the oxidation of the alloy is accompanied by a gradual formation of alumina on the surface.

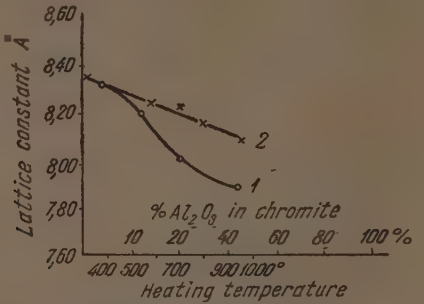

Fig. 2. Variation of lattice constant: *1*, the oxide film of an alloy with 70% Fe, 25% Cr and 5% Al as related to the temperature of oxidation; *2*, chromite, in relation to the content of alumina

As the amount of aluminium oxides grows, the oxide layer gradually thickens and its specific gravity declines. At a certain thickness of the film its continuity is broken and its upper layers are partially destroyed. The latter make up that part of oxides which is determined from loss of weight on testing alloys for thermostability (1).

While testing the alloy for oxidation at 1200° C in long runs with alternate heating and cooling at intervals of 12 and 42 hrs, we collected this portion of the oxide film for additional investigation in the pure state. Chemical and X-ray analyses were carried out. The chemical analysis of the collapsed portion of the oxide film has shown that it consists of 98.72 per cent of alumina, 0.71 per cent of chromic oxide and 0.80 per cent of ferric oxide, in other words, nearly all of it is pure alumina.

The X-ray data obtained for the oxide film and for pure alumina (specially prepared to the purpose) have revealed in both an identical structure with a lattice constant, corresponding to pure γ-Al_2O_3.

Conclusions. 1. Electronographic and partially X-ray and chemical analyses have furnished corroborative evidence to the effect that the oxidation of Fe-Cr-Al solid solutions does not have the same character at moderate and high temperatures.

2. At moderate temperatures an isomorphous mixture of Fe, Al and Cr oxides of the type of spinels ($RO \cdot R_2O_3$) with a cubic crystalline lattice is formed on the surface of the alloy.

3. With increasing temperature of oxidation the lattice constant of the solid solution of oxides decreases and in the limit approaches the constant of the pure γ-Al_2O_3 lattice.

4. These facts are in agreement with selective oxidation of aluminium at high temperatures at the expense of atmospheric oxygen and of the iron and chromium oxides of the oxide film.

5. The oxide film formed on the surface of the alloy in the form of pure alumina crumbles easily and constitutes the portion that is determined when thermostability is investigated by the loss-of-weight method. This portion of the oxide film has no protective properties.

6. The thermostability of the Fe-Cr-Al solid solutions is determined by the formation of an oxide film in the form of solid solutions of iron, chromium and aluminium oxides; by the aluminothermic reduction of Fe and Cr oxides in the oxide film and by the rate of diffusion of aluminium during the process of oxidation of the alloy.

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BIOCHEMISTRY

REVERSIBLE ACTION OF INVERTASE IN BARLEY

By S. ELIZAROVA

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Studies devoted to the reversible action of enzymes created the possibility of a deeper insight into the rôle of enzymes and into the biochemical processes that take place in a vegetable organism. Peculiar interest is invited by processes connected with stage-by-stage development. Biochemically, of great importance would be to find out whether the enzymic indices are hereditary, especially in naturally developing plants. In order to solve this question the authors undertook to investigate the synthesizing and hydrolysing action of the invertase enzyme. The work was carried out with 11—12-day-old seedlings of barley belonging to various ecological types sharply differing as to their geographical origin. Distichum and polystichum barley were taken for this investigation.

With the aim to follow up the divergence of characters in the progeny; we investigated hybrids obtained by crossing both contrasting and identical forms for the indices of the trend of invertase action. We were also interested to find out whether varietal differences persist not only in seedlings, but in adult plants, while these pass through development stages, as well. The trend of invertase action was investigated at the period when the plants start flowering. Eight basic barley varieties were taken for analysis.

M e t h o d. The synthesizing and hydrolysing action of the invertase enzyme was studied by the method of quantitative determination of the reversible action of this enzyme by the method of vacuum infiltration. The first to apply this method was Björksten; later on it was used by Mothes when studying protein metabolism in higher plants.

Within recently, owing to works by A. L. Kursanov (1); this method was more thoroughly developed; and began to enjoy wide application.

For the analysis were taken the first leaves of 11-day-old barley seedlings grown in light at a temperature of 18—20° C*. Sampling was done always at the same hour, viz. at 10 h. a. m.

The leaves were infiltrated with solutions of sucrose and monosucrose (invert) at a concentration of 0.1—0.2 mol. According to Kursanov, the osmotic pressure of these solutions does not affect appreciably the enzymic reactions in cereal crops, leading to no deviation from their normal rate or trend. Infiltration was made to last 30 min.; exposure, two hours and a half. After this the seedlings were killed with hot steam, and sugars determined after Bertrand.

The data of the analysis were; as usual; recalculated for one hour of enzymic activity per 1 g of dry weight.

* Either the first or the second leaf may be taken for analysis, the process being similar at this age in both.

Investigation of the Barleys. In order to investigate the reversible action of the invertase enzyme, 20 different varieties of barley were taken.

Four of them were being grown for several years at the Polar Experimental Station of the All-Union Institute of Plant-Breeding at Chibiny. The seeds were collected in 1938 and 1940. 11-day-old seedlings were investigated.

The data of the analysis have shown that in the varieties *Nutans* Uraiste, *Sublatiglumatum*; *Maskin bygg.*, *Pallidum* Pioner, the enzymic process of the invertase tends towards synthesis. In *Nutans colchicum* 010/30, *Brachyatherum*; *Pallidum* «045», Holt, Jotum, *Nigrinudum* etc. the enzymic process is liable to develop into hydrolysis.

In the barleys *Nutans* golden and *Pallidum* Arkhangelsky the relation between the indices of synthesis and hydrolysis are near to unity.

Seedlings grown from seeds harvested at different years were investigated. It was found that the trend of the enzymic process is constant, only the numeric index of the enzymic activity being subject to fluctuation (Table 3).

When seedlings grown from seeds of one and the same crop were subjected to repeated investigation at various periods of the year, the numerical index of the enzymic activity was also found to fluctuate.

Table 1

Synthesizing and Hydrolysing Activity of Invertase in Living Tissues of Barley (in 1 hour per 1 g of dry matter)

Variety and origin	Synthesis	Hydrolysis	Ratio synthesis : hydrolysis
Nutans Sch. Uraiste 18614 (Finland)	13.77	11.13	1.2 : 1
Nutans Sch. golden 8350 (Sweden)	13.13	13.15	1 : 1
Nutans Sch. *colchicum* 010/30 (Western region)	11.47	29.8	1 : 2.6
Nigrinudum 9225 (Abissinia)	6.68	20.33	1 : 3
Sublatiglumatum 6088 (Afghanistan)	11.04	10.67	1 : 1
Brachyatherum 625/0392 (China)	8.33	29.62	1 : 3.6
Pallidum Ser. Arkhangelsky	10.71	27.36	1 : 2.6
Pallidum Ser. «045» 8269 (Krasny Kut)	12.96	24.04	1 : 1.9
Trifurcatum 3270	5.75	5.12	1.1 : 1
Pallidum Pioneer	13.1	8.9	1.5 : 1
Maskin bygg. 26789	14.1	2.9	4.9 : 1

The numerical indices made it possible to determine the individual range of fluctuations of invertase activity for each variety separately.

We investigated barley varieties *Maskin bygg.*, *Nutans* Uraiste, *Colchicum* 010/30 from different localities of cultivation (Moscow, Tashkent, Chibiny). The trend of invertase activity was invariably the same; though the numerical index showed fluctuations. Such a persistent tendency of the enzymic activity should be taken to mean that this character is typical of a given barley variety. What may then be the cause of the variations of the numerical index? Intensity of solar radiation; variation in the size of the point of growth; and the various intense chemical processes connected herewith, all these factors are responsible for the variations in the numerical index of the enzyme.

Trend of Invertase Action during the Flowering Period. As well known, in the course of its life cycle the plant passes from one developmental stage to another. This transition should be accompanied by internal biochemical changes. Corresponding data are brought out by Sissakian (2), Rubin and Lutikova (3) in their work on sugar-beet, by A. Morozov (4) in work on perennial plants and meadow grasses.

We investigated the earliest stage of flowering when barley which is a self-pollinator is still in stalk, and the tops of the beards do but peep out of the upper wrapping leaf.

The second leaf from the top was taken for analysis; sampling was made at 10 a. m. Six varieties of barley were analysed: distichum *Nutans* Sch. Uraiste, *Nutans* golden; *Nutans colchicum* 010/30; polystichum *Sublatiglumatum*, *Pallidum* Arkhangelsky; *Pallidum* «045».

Table 2

Action of the Invertase Enzyme during the Flowering Period

Variety and origin	Synthesis	Hydrolysis	Ratio synthesis : hydrolysis
Nutans Sch. *colchicum* 010/30	14.1	3.81	3.7 : 1
Nutans Sch. Uraiste 18614 (Finland)	14.4	2.8	5.1 : 1
Nutans Sch. golden 8350 (Sweden)	9.71	1.12	8.7 : 1
Sublatiglumatum 6088 (Afghanistan)	10.44	3.41	3.1 : 1
Pallidum (Arkhangelsk)	7.9	2.89	2.7 : 1
Pallidum Ser. «045» 8269 (Krasny Kut)	6.34	0	6.3 : 0

From the data tabulated above it is evident that at this stage of development the action of the invertase enzyme is invariably towards synthesis, irrespective of variety.

It should be noted that in *Nutans colchicum* 010/30 and others; in whose seedlings the enzymic process showed a trend towards hydrolysis, it underwent a sharp change at the stage of flowering and proceeded in the direction of synthesis characterized by extremely high numerical indices with that. Thus, *Nutans* golden and others, whose seedlings gave vague, indistinct indices of the trend of the enzyme's action, gave now an exceedingly high numerical index of its activity.

Consequently, at this stage of development the process is in all varieties shifted towards synthesis, and all varietal distinctions are obliterated.

Curiously enough; the process tends toward synthesis both in the first wrapping leaf and in the third from the top. Unlike Nilov (1939), we found in barley no «synthetic» or «hydrolytic» leaves: the whole vegetable organism is working in the same direction.

Chibiny Barleys. The Polar Experimental Station of the All-Union Institute for Plant-Breeding kindly supplied us with seeds of barleys bred from local Karelian varieties, seeds of Russian and Scandinavian barleys which have been cultivated at Chibiny for several years, and with their hybrids. Analysis was made of seedlings of barleys grown from seeds collected in 1938 and 1940 from two plots: 1) one with usual soil added mineral fertilizers and 2) another with swampy soil.

Table 3

Synthesizing and Hydrolysing Activity of Invertase in Barley of the Polar Experimental Station at Chibiny

Variety	Soil	Year of harvest	Synthesis	Hydrolysis	Ratio synthesis : hydrolysis
Karelian K 2/10	Mineral	1938	4.7	6.8	1 : 1.8
» K 2/10	»	1940	3.6	6.5	1 : 1.
» K 2/10	Swampy	1940	1.9	3.5	1 : 1.8
» K 2/11	Mineral	1938	14.5	8.6	1.7 : 1
» K 2/11	»	1940	15.3	9.8	1.6 : 1
» K 2/11	Swampy	1940	12.1	6.2	1.9 : 1
Maskin bygg. 26789	Mineral	1940	15.2	2.6	5.8 : 1
Pallidum Holt	»	1938	2.1	5.2	1 : 2.5
» »	»	1940	3.7	20.7	1 : 5.6
Pallidum Pioneer	»	1939	7.1	7.6	1 : 1.1
»	»	1940	5.0	8.9	1 : 1.8
Pioneer × Holt	»	1940	5.8	5.5	1.1 : 1
Maskin bygg. × Japanese 11198	»	1940	2.6	11.8	1 : 4.5
Do, 4313	»	1940	8.7	17.6	1 : 2
Jotum × *Maskin bygg*	»	1940	13.4	5.1	2.6 : 1

When analysing the data obtained, it can be said that the trend of invertase activity in seedlings from seeds collected in 1938 and 1940 and in those from seeds grown on different soils is constant. It is only the magnitude of the numerical index which varies according to cultivation conditions.

In the variety Karelian K 2/10 both from the swampy and the mineral plot, the activity of invertase proceeds stably towards hydrolysis. In K 2/11 the picture is reverse: the activity of invertase is shifted towards synthesis.

It is noteworthy that seedlings of *Maskin bygg*, both from seeds grown during several years at Chibiny and from seeds grown in Tashkent, show an alike trend of the enzymic activity; and it is only the numerical index of the enzyme that is subject to fluctuation (Tables 1 and 3).

Conclusions

The trend of the activity of the invertase enzyme is a typical physiological character of barleys. The data available give no ground to relate this character with morphological variations.

At the time of flowering the trend of the process changes sharply, and goes on towards synthesis in all varieties without any exception.

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GEOLOGY

ARENACEOUS ROCKS IN THE VISEAN DEPOSITS OF SECOND BAKU AS OIL RESERVOIR ROCKS

By P. P. AVDUSIN

(Communicated by S. S. Nametkin, Member of the Academy, 10. V. 1943)

In the problem of the presence of oil in the Second Baku; Volga-Ural region, along with the solution of geotechnic and geochemical problems, the question of the reservoir rocks of liquid hydrocarbons, their origin, facies, and physical properties (capacity, permeability, etc), is one of the most vital importance.

The geographical distribution of facies of reservoir rocks assists in determining the trend of the quest for oil; the structure of reservoir rocks and their mineralogical composition enables us to establish with greater accuracy the economic capacity of oil fields and to determine the nature of the migration of the oil flow in the bed.

Taking part in the work of the expeditions of «SOPS» of the Academy of Sciences, I have been for the last three years engaged in the study of reservoir rocks in Permian and Carboniferous deposits of the Volga-Ural region.

The arenaceous sediments of the Lower Carboniferous, of the so-called coal-bearing series, as reservoirs of economic oil accumulations; are of an exceptional interest; and it is with the brief results of a comparative analysis of these deposits within the territory of the Second Baku that I intend to acquaint the reader in the present paper.

Within the greater part of the territory of the Volga-Ural region investigated by us, the coal-bearing formation (C_1^h) is represented by a uniform complex of frequently alternating argillo-arenaceous, locally coal-bearing and carbonate sediments.

The origin of this peculiar facies of sediments of the Visean basin is related to large orogenic movements of the European country, which occurred towards the close of the Tournaisian age.

By the beginning of the Visean epoch the Russian plain represented a vast basin that accumulated the terrigenous material removed from the more elevated areas of the continent.

An analysis of the facies of the arenaceous sediments of the coal-bearing formation and a study of their granulometric and mineralogical composition show that the chief masses of clastic material were supplied to the coal-bearing basin from the west, north-east and south-east; while the erosional relief of the western and north-eastern parts of the continent was more or less quiet and gentle, in the extreme south-east the Lower Carboniferous basin was fringed by a mountainous country with a highly dissected relief.

Huge masses of clastic material carried during the comparatively short age of the coal-bearing formation to the area of the depression of the Russian plain

indicate a strongly developed hydrographic network of the denudation areas.

Interesting palaeolithic features of the European country during the Visean are given by the mineralogical investigations of the sand of the coal-bearing formation (see table).

These investigations enable two sharply differentiated terrigenous-mineralogical provinces of the sediments of the coal-bearing basin to be distinguished, namely a quartz zone, comprising the central and northern parts of the Volga-Ural region, and a southern, feldspar-micaceous province. The abundance of quartz in the coal-bearing sediments of the central and northern parts of the plain points to a predominant development of acid (granitic) magmatic rocks and their derivates in the northern and western supplying provinces. In the geological structure of the southern mountainous country a highly variegated lithological complex took part. Among the clastic material of the Lower Carboniferous deposits of the area between the Ural and the Sakmara rivers, there have been discovered fragments of diverse types of limestones, sandstones, clays and clay shales, silicites, quartzites, chloritic schists, diabases, and porphyrites.

The thickness of the arenaceous sediments of the coal-bearing series is subject to considerable variations, from 8—12 m in the central part of the region (Syzran, Tuymazy, and others) up to 200 m and over in the north-eastern regions (Kizel and Vishera). The changes in the thickness of the sandy sediments of a regional nature are associated with the peculiarities in the lithogenesis of the sediments C_1^b; local, sometimes very sharp changes of thicknesses are due to the geomorphological peculiarities of the pre-Visean relief.

A comparison of the data concerning the physical properties of the reservoir rocks—their porosity, permeability, etc.—of the coal-bearing formation with the results of their lithogenetic analysis enables three zones to be distinguished within the territory of the Volga-Ural oil zone. The economic indices of the reservoir rocks of these zones are different.

The zone of development of the best oil reservoir rocks of the Visean stretches in belt of a latitudinal trend to the central part of the Russian plain. Its eastern boundary is formed by the Ishimbay region, while in the west the zone extends beyond the right bank of the Volga, to an area not yet investigated by us.

The Visean reservoir rocks of the 1st zone are represented by pure quartz sands, highly graded. An analysis of the diagrams showing the mechanical composition of these sands reveals that the maximum of the granulometric composition curve when moving from west to east is markedly shifted to the left, i. e. the average grain size of the sandy sediments decreases in this direction.

The morphological uniformity of the clastic material of the arenaceous rocks (C_1^b) of this zone brings about a grain packing closely approaching the tetrahedral scheme, producing an ideal type of pore space structure with high indices P_{eff} (21—23 per cent) and isometric forms of sections of the pore channels. The hydraulic characteristic Φ, determined on a number of specimens of friable oil-bearing sands from deep-well cores from the Samara Bend, Tuymazy and Bugurusian, yields values varying within the range of 0.25 to 0.38*.

The high indices of P_{eff} and Φ cause an excellent permeability of the rocks for oil: in the friable varieties of sands the filtration factor is 0.5—2.0 darcys. Such structural indices characterize the sands of the coal-bearing formation of the central zone as reservoir rocks of classes A, B and C (clayey varieties)**.

The thickness of the reservoir rocks of the coal-bearing formation within the territory of the first zone gradually increases in a western and northern direction: at Ishimbay (well No. 101) the thickness of the aleurite bands in the coal-bearing formation is equal to some centimeters; in the sections of Tuymazy wells the thickness of the sands increases to 8 m, and in the regions of the Samara Bend, to 12 m.

* With magnifications of drawings $K = 50$ and radius of drawing $R = 7.5$ cm.

** The nomenclature of reservoir rocks follows the classification developed by the author in collaboration with M. A. Tsvetkova [1].

Mineralogical Composition of the Sandy Rocks of the

Name of region	Number of analyses	Minerals with a specific gravity					
		Quartz	Feldspars	Micas	Glauconite	Minerals of clays and clayey forms	Fragments of rocks
Northern zone							
Kizel region	6	85—93	3—7	1	—	2	
Krasnokamsk region	5	80—87	9—15	1	—	1—5	
Vozhgly »	5	65—94	5—16	—	—	1—80	
Chistopol »	18	85—96	2—9	0—1	0—1	1—9	1—7
Central zone							
Ishimbay region	1	91	4	—	1	4	
Tuymazy »	5	79—91	6—18	1—2	—	1	3
Buguruslan »	2	80	18	—	—	—	2
Syzran »	15	76—93	5—12	1	—	—	2
Southern zone							
Area between the Ural and the Sakmara rivers	7	4—7	28—29	1—3	0—1	3—9	51—64

Name of region	Minerals with a						
	Spinel	Rutile	Zircon	Anatase	Tourmaline	Brucite	Carbonates (Ca, Mg)
Northern zone							
Kizel region	—	1—5	5—43	0—1	2—3	0—1	1—9
Krasnokamsk region	—	1—2	13—26	1—1	8—17	—	1—6
Vozhgly »	—	1—2	2—18	0—1	1—23	0—1	—
Chistopol »	0—1	1—5	1—30	0—1	1—21	—	—
Central zone							
Ishimbay region	—	3	27	—	17	—	—
Tuymazy »	—	1—1	10—25	—	9—18	—	—
Buguruslan »	—	1	22	—	10	—	—
Syzran »	—	—	12—30	0—1	1—30	0—1	0—15
Southern zone							
Area between the Ural and the Sakmara rivers	1—10	0—1	1—1	—	1 to 2	—	1—18

* The table gives the mineralogical composition of the fraction with a particle size

** The rocks were treated with 10% HCl.

*** The specimen was treated with HNO_3 to dissolve the pyrite.

Viscan within the Territory of the Ural-Volga Region*

< 2.75**								
Carbonaceous residues	Siliceous skeletons of organisms	Content of heavy fractions, %	Pyrite	Magnetite and ilmenite	Red brown iron oxides	Non-ore opaque minerals	Garnet
1—3	—	0.15—2.15	3—35	2—4	3—15	11—41	0—2
1—1	0—1	0.13—0.40	5—33	6—18	2—8	12—42	1—1
—	—	0.01—3.75	6—2	1—45	1—73	5—57	1—2
0—1	0—11	0.45—2.76	14—90	1—60	1—52	14—100	0—1
—	—	0.5***	—	—	4	40	1
1—8	0—1	0.66—5.00	3—46	3—16	1—12	22—53	0—1
0—1	0—1	2.00	10	8	8	42	—
1—1	0—1	0.21—0.66	20—42	8—35	1—6	10—22	1
—	0—2	0.86—1.61	8—20	1—10	12—31	6—24	0—1

Continued

specific gravity > 2.75

Biotite	Green mica	Colourless mica	Amphiboles	Pyroxenes	Minerals of epidote and zoisite group	Staurolite	Barite	Celestine	Titanite	Corundum	Disthene	Tremolite
0—1	—	1—8	—	—	0—1	1—1	0—1		—	0—1	—	—
—	1—1	2—12	—	—	0—1	0—1	—	—	—	—	—	—
0—1	1—33	1—21	—	—	0—1	0—1	0—2		0—1	—	—	—
0—1	1—5	1—21	0—1	—	0—1	0—1	—	—	0—1	—	0—20	—
1	5	—	—	—	1	—	—	—	0—1	—	—	—
1	—	2—20	—	—	—	1	1	—	—	—	—	—
—	—	2	—	—	0—1	—	—	—	—	—	0—7	—
—	1—2	1—4	0—1	0—1	0—1	—	—	—	—	—	1—2	—
—	2—4	3—19	—	—	0—2	—	—	—	0—1	—	—	1

of 0.25 to 0.01 mm.

North of the Central (1st) zone stretches a vast area of the Russian plain, distinguished by somewhat different conditions of sedimentation at the time of the coal-bearing formation. Along with well-graded sediments (reservoir rocks of classes A and B), at times bands of quartz sands of considerable thickness are encountered, graded worse and carrying a substantial admixture of aleuritic and clayey fractions. The shape of the fragments of the clastic material of sands is often irregular and sharp-angular.

The poorly graded condition of the clastic material and the admixture of aleuritic and clayey fractions result in a lower filtration power of these sandy rocks of the Visean than of the sands of the 1st zone, and induces us to refer the bulk of them to reservoir rocks of classes B, C and D.

Over a considerable area of the 2nd zone the thickness of the sandy reservoir rocks is greater than that observed in the Central part of the European plain. Thus, in the Kizel region the thickness of the sandy bands is 200 m; in the near-Kama regions, 35 m; in the Chistopol region, 45 m; an insignificant thickness of sands has been recorded at Vozhgly (3 m).

A peculiar terrigenous complex takes part in the formation of sandy facies of the Lower Carboniferous of the 3rd zone, comprising the territory south of the latitude of the town of Chkalov.

The clastic material of the Visean sediments of this zone is represented by products of decomposition of clayey carbonate, and tuffaceous rocks which took part in the structure of the southern provinces supplying the Lower Carboniferous basin. The sandy rocks are represented by polymict varieties with a considerable admixture of argillaceous material.

While the complete porosity indices are high, the effective porosity of the Visean sandy rocks of the southern zone is not very large. P_{eff} is 8—11 per cent. The irregular, angular shape of the grains of the clastic material and the admixture of clayey cement produce a complicated structure of pore spaces with a large perimeter of sections of the pore channels, reducing the velocity of the filtration flow. Along with reservoir rocks of class C, in the Lower Carboniferous sandy rocks of the 3rd zone sand bands of classes D and E are common.

The thickness of the sandy rocks of the Lower Carboniferous rocks of the southern zone varies within a range of 50 to 80 m. markedly increasing in a southern direction.

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PLANT PHYSIOLOGY

ABSORPTION OF SALTS BY COTTON FROM SOLUTIONS OF HIGH CONCENTRATION

By P. A. HENCKEL, S. S. KOLOTOVA and N. N. SHCHERBAKOV

(Communicated by A. N. Bach, Member of the Academy, 20. VII. 1943)

In an earlier paper on pre-sowing treatment for salt resistance we have shown(1) that germinated seeds of wheat, subjected to a short action of salt solutions (an 8 per cent solution of a Vant-Hoff's salt mixture, or a molar solution of sodium chloride) increase in salt resistance considerably. The increased salt resistance of the experimental plants has been found in that investigation to be connected with a decrease of absorption of chlorine which was present in the surrounding medium in high concentration.

In the spring of 1940 we started similar experiments with American cotton, variety 8517, in the experimental field of Fedchenko, Central Asia (2,3). The absorption was studied on the plants that had been given a pre-sowing treatment with different salt solutions. The germinated seeds of all test-sets were treated for 1.5 hours; the set with boric acid formed no exception. This set was taken by us on the basis of the data by Novikov and Sadovskaya (4); who have been able to show that treatment with boric acid during 24—48 hours considerably increases the salt resistance of cotton. Unlike Novikov, we treated germinated seeds instead of dry, and shortened the period of action down to 1.5 hours.

The plants were grown in water cultures on Knops' mixture for a period of 24—40 days and then were taken out to test them for the intensity of absorption of Cl, SO_4 and PO_4 ions. The duration of the absorption tests was 24—48 hours. The absorption was estimated from the content of the respective ions in the solution outside the plant.

Chlorine was determined by titration with silver nitrate, sulphate by the benzidine method; and phosphoric acid according to Dénigès. The absorption was always referred to a unit volume or a unit surface of the root-system, in accordance with the method of Sabinin and Kolossov (5).

In treating the seeds and in the absorption tests we used Vant-Hoff's solution. The sodium chloride in this solution was taken in molar ratio instead of per cent, as done by Vant-Hoff. With regard to the remaining components of the mixture, there was no change. Thus, we used the same solution as in our earlier work (1). The modified solution of Vant-Hoff had a considerably increased content of sulphate salts (sodium sulphate). The solution of calcium chloride was taken in 0.5 molar concentration, and the concentration of boron was 0.4 per cent of boric acid.

Let us turn in the first place to the results of the chlorine absorption tests with rather high concentration of Vant-Hoff's solution.

As seen from Table 1, the rate of absorption of chlorine is much lower in plants that received a pre-sowing treatment with salt solution. The absorption of chlo-

Table 1

Absorption of Chlorine and SO_4 Ions by 38-Day-Old Seedlings of Cotton in 48 Hours

(from a 0.2 normal Vant-Hoff's solution as modified by the authors)

Experimental set	Number of plants	Root volume in cm^3	Total absorption in mg	Absorption in mg per 1 cm^3 of root	Mean	% of absorption in respect to control
Absorption of Chlorine						
Control	10	6.5	13.0	2.0	2.0	100
0.3% Vant-Hoff's solution	10	8.0	8.3	1.0	—	—
Do	10	4.5	7.8	1.6	1.3	64
Modified Vant-Hoff's solution	10	7.0	9.3	1.3	—	—
Do	10	7.5	7.3	1.0	1.15	57
Boron	10	6.0	4.7	0.8	0.8	38
Absorption of SO_4						
Control	10	6.5	184.0	28.3	28.3	100
0.3% Vant-Hoff's solution	10	8.0	124.8	15.6	—	—
Do	10	4.5	177.4	34.8	25.2	88
Modified Vant-Hoff's solution	10	7.0	144.5	29.0	—	—
Do	10	7.5	157.7	21.0	25.0	88
Boron	10	6.0	164.2	27.4	27.4	95

rine by test-plants is about 50 per cent as compared to the control. Different tests show a somewhat different picture as regards the per cent of absorption, but the trend of the process is always the same. The absolute values of absorption in these tests are always small, as is usual for the absorption of salts from high concentrations.

Similar results have been obtained in the sulphuric acid anion tests (Table 1), yet here the difference between experimentals and controls is by far less sharp.

The data presented in Table 2 are referred to a unit volume or a unit surface area of the root-system. It may be seen that the results of computation according to the two different methods have an analogous picture.

Table 2

Absorption of Chlorine by 20-Day-Old Cotton Seedlings in 48 Hours

Experimental set	Absorption			
	per 1 cm^2 of the root-system in mg	in %	per 1 m^2 of the root-system in mg	in %
Control	16.5	100	2.7	100
0.3% Vant-Hoff's solution	8.8	53	1.0	38
0.5 $CaCl_2$	10.6	64	1.5	55
0.5% Vant-Hoff's solution	9.7	59	1.13	44
Boron 0.4%	15.5	94	—	—

There naturally arises the question; however, as to how will plants that have received the pre-sowing treatment take up salts from solutions of low concentrations.

We were especially interested in this problem, because it bears upon the normal provision of plants with mineral substances. Should it be found that the mineral substances necessary for the plant and available in the soil solution in rather low concentrations are taken up by the treated plants in greatly reduced quanti-

ties, this might considerably limit the yield of these plants on saline soil. In other words, notwithstanding their high salt resistance, these plants might increase their yeild to a comparatively low extent, because of a strong reduction of the uptake of mineral nutrients.

For that purpose we have studied the absoption of phosphoric acid from a normal and from a diluted solution of Knop (Table 3).

Table 3

Absorption of PO_4 Ion by 26-Day-Old Cotton Plants from an 0.2 Knop Solution in 48 Hours ($t° = 28.4°$)

Experimental set	Number of plants tested	Root volume in cm^3	Total absorption of PO_4 in mg	Total absorption of PO_4 in mg per 1 cm^3 of root	Mean	Total absorption of PO_4 in % to control
Control	10	4.5	0.82	0.18	—	—
Do	10	4.5	0.80	0.17	0.17	100
0.3% Vant-Hoff's solution	10	4.5	0.79	0.17	—	—
Do	10	4.5	0.66	0.15	0.16	94
$CaCl_2$	10	3.5	0.69	0.20	—	—
Do	10	4.0	0.66	0.16	0.18	103
Modified Vant-Hoff's solution	10	6.0	1.25	0.20	—	—
Do	10	6.0	1.18	0.19	0.19	111
Boron	5	4.5	1.80	0.39	—	—
Do	5	4.5	1.73	0.38	0.38	220

From Table 3 it may be seen that phosphoric acid is taken up by the treated and untreated plants in equal quantities, or even somewhat more of it is absorbed from the solution by the former.

Similar tests were run with low concentrations of chlorine. Like phosphoric acid, chlorine, when supplied in low concentrations, is absorbed by test and control plants in more or less equal quantities. This appears to be a very interesting result, since from it arises the idea of a great difference in the uptake of the same substance by treated plants, according as its concentration is high or low.

Table 4

Absorption of Chlorine Ion by 34-Day-Old Cotton Plants from 0.02 Normal Vant-Hoff's Solution in 48 Hours

Experimental set	Number of plants tested	Root volume in cm^3	Total absorption of Cl in mg	Absorption of Cl in mg per 1 cm^3 of root	Mean	Absorption of Cl in % to control
Control	10	6.5	1.71	0.26	0.26	100
Do	10	—	—	—	—	—
0.3% Vant-Hoff's solution	10	8.6	2.74	0.32	—	—
Do	10	8.0	3.26	0.41	0.36	137
Modified Vant-Hoff's solution	10	7.0	3.26	0.46	—	—
Do	10	7.5	3.26	0.43	0.45	171
Boron	10	6.0	1.20	0.20	0.20	75

Whereas in the first case there was a decrease of absorption, in the second case the absorption was more often observed to increase as compared to the control.

In order to get a clear understanding of the results obtained, one has to turn to the investigation of salt absorption by the plant from solutions of high concentrations.

It would seem that in the region of high concentrations the absorption of ions by plants is pathological rather than normal. Apparently, a high concentration injures the plasm; and a passive absorption of salts by the plant becomes impossible. In this case we are faced with a certain deviation from the general statement established of late by several authors concerning the active rôle of the plant in the absorption of mineral substances. We shall not dwell here on this problem which was recently dealt with in a monograph by Sabinin (6); except to say that according to our conception the absorption of salts from a solution is greatly influenced by transpiration, if the concentration of the salts is high.

A special experiment carried out by us has supported this assumption. In this experiment the absorption of chlorine was studied in the presence of, and in an almost complete absence of, transpiration. With this object in mind the vessel with the plant was covered by a glass bell lined on the inside with a moist paper filter. Parallel tests were run with a glass bell in a diffused light. As seen from Table 5, the absorption of chlorine ion is nearly 100 per cent higher in a transpiring plant than in a plant prevented from transpiration. With small concentrations of chlorine in the solution no such law appears to be observed; as is seen from Table 5.

Table 5

Absorption of Chlorine Ion from Vant-Hoff's Solutions in 12 Hours with Transpiration Eliminated

Experimental set	Absorption of chlorine in mg	Volume of root-system in sm^3	Absorption of Cl in mg per 1 cm^3 of root-system
0.1 normal Vant-Hoff's solution			
With transpiration	27.6	6.6	4.2
Do	26.0	6.7	4.0
Without transpiration	15.0	6.4	2.3
0.02 normal Vant-Hoff's solution			
With transpiration	5.0	8.6	0.57
Without transpiration	3.0	8.4	0.35

The objection that shading may influence the results of the first tests should be refuted on the ground that the decrease of absorption in the darkness is not 100 per cent as is the case with eliminated transpiration, but about 30 per cent (Table 6).

Table 6

Influence of Darkness on Absorption of Chlorine by 10-Day-Old Seedlings in 12 Hours

Experimental set	Absorption of chlorine in mg	Volume of root in cm^3	Absorption of Cl in mg per 1 cm^3 of root volume
In light	8.5	2.05	4.6
	8.5	2.00	4.2
In darkness	10.5	2.70	3.8
	9.5	2.70	3.5

The material referred to undoubtedly corroborates our assumption as to the injury of the plasm by salts that are contained in high concentrations by the surrounding medium. These considerations explain also why the plants treated previous to sowing by salt solutions absorb much less salt when its amount in the medium is considerable.

As has been pointed out by us elsewhere ([3]); cotton that has been given a presowing treatment proves more stable to the toxic effect of salts. Its plasm sustains a smaller injury, and therefore the rate of passive absorption of salt is lower.

In the region of small salt concentrations where there is no injury to the plasm, the salts are absorbed normally, which is connected with the active rôle of the plant itself. Here a more or less strong absorption is observed according to the condition of the test-plant. Usually it is somewhat higher in the latter, because their root-system grows at a somewhat higher rate. Our explanation is analogous to Kertis' ([7]) opinion about this question.

From what has been said here it will be obvious that passive absorption of salts is a matter of great importance with plants grown on saline substratum. The phenomena described take also place in natural surroundings where the formation of lesions due to salts in the form of spots is often observed as a result of salt poisoning.

It may be supposed that measures intended to reduce transpiration will contribute to a better preservation of plants grown on soil high in alkali.

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PLANT PHYSIOLOGY

WHITEWASHING OF THE PLANTS AS A MEANS TO IMPROVE THEIR WATER-REGIME AND INCREASE THE YIELD OF SUGAR-BEET

By I. I. KOLOSSOV

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When growing sugar-beet under conditions prevailing in the Kirghiz SSR during the hot season (July, August), one may always observe the leaves to wilt and droop at midday, this phenomenon being due to water deficiency. At the North Caucasus where beet is cultivated without irrigation, withering ultimately results in a decay of a considerable part of the leaves. The growth of the root and sugar accumulation in it is thereby delayed.

At the suggestion of Prof. E. V. Bobko, in 1932 at the Pervomayskaya experiment station (North Caucasus) field experiments were undertaken, involving whitewashing of the sugar-beet leaves. The idea was to increase in this way the ability of the leaves to reflect sun rays and thus to reduce overheating which through intensified evaporation brings about withering of the leaves, and occasionally their dying-off.

Preliminary tests carried out during 1931 in pots by G. K. Davidov under the guidance of Prof. Bobko, consisted in covering the leaves of the experimental plants with a 10 per cent suspension of chalk in water. These tests showed the transpiration in «whitewashed» plants to decrease by 11 per cent, while the osmotic pressure of the leaf sap dropped from 17.8 to 14.2 atmospheres(1).

The experiments run at the Pervomayskaya station within 1932—1941 showed that when whitened the leaves were less liable to wilting. In particular, Morgazky's tests showed that at the hours when the surrounding air was at its temperature maximum, the temperature of the whitewashed leaves was by 4.5° C lower than that of the controls. Tests by Radugin (1) carried out at the same station showed that the temperature of the soil under the experimental plants was also reduced considerably.

As a result of the treatment, the plants were found to improve. and there was a better yield of the root and a higher output of sugar.

On the ground of the work described we started in 1932 experiments both in pots and in field involving whitening of the first-year sugar-beet under conditions of the Kirghiz SSR. Along with these, tests were made with whitening of sugar-beet plants left to run seed.

Method. The plants of the pot experiment were grown in soil cultures, on Ukradyga mixture (2), soil humidity ranging within 60—80 per cent to its total moisture capacity. Each vessel was made to contain 7 kg of air-dry soil. The tests were run at 12-fold replication.

The field experiment with first-year beet and plants left to run seed was run at the Kirghiz breeding station. In the former case the area of the plot was 100 m^2;

replication tenfold, the rows being 60 cm apart; in the latter case, they were 71 cm apart.

In the test with plants left to run seed the roots of each of the three runs were divided into 7 groups according to their weight. The first group comprised roots of 525—600 g; the second; of 601—675 g; the third, 676—750 g; the fourth; 751—825 g; the fifth; 826—900 g; the sixth, 901—975 g; and the seventh, 976—1050 g. Each group was planted separately, so that the experiment was run at 21 replications.

For whitening use was made of a 16 per cent suspension of quicklime added with 2 per cent of treacle. In the pot experiments a common pulverizer was applied, in field experiments a knapsack sprayer. The expenditure of lime in the field experiment made up about 10 kg per 100 m².

In the course of the summer, the plants were sprayed 7 times in the pot experiments; in the field experiment, first-year beet 5 times and plants left to run seed twice.

First-year beet was tested for the effect of whitening upon the crop of root and upon transpiration; the latter was determined in the pot experiments after the loss of weight by the pots, in the field experiments by the loss of weight by the severed leaves of a definite node after these had been exposed for 5 minutes to sunshine.

Results of Experiments with First-Year Beet. Transpiration measurements made in plants of both pot and field experiments show that whitening reduces the water expenditure by plants. In pots, where the humidity was 80 per cent to total moisture capacity, after four treatments (from July 28 till Agust 11) transpiration was found to be by 13.6—22.9 per cent lower than in untreated plants (Table 1).

Table 1

Transpiration of Plants in Pot Fxperiment

Exper. set	Soil humidity in pots in % to total moisture capacity	Mean 24-hour-day transpiration during 5 days upon whitening at various date, in g per pot and in %										Transp. coefficient for period of growth calc. per 1 g of raw substance	
		28, 29, 30.VII		11.VIII		29.VIII		9.IX		18.IX			
		g	%	g	%	g	%	g	%	g	%	g	%
Unwhitewashed plants	80	335	100	361	100	500.6	100	449	100	382	100	71.0	100.0
Whitewashed plants	80	263	86.4	278	77.1	527	95.7	457	102	420	110	61.4	86.4
Effect of treatment (−decrease, + increase in transpiration)		−41.3 ±25.8		−82.7 ±45.7		−23.6 ±14.9		+8.0 ±8.6		+38.0 ±21.7			
Unwhitewashed plants	50	272.9	100	253	100	381.2	100	289	100	267	100	61.8	100.0
Whitewashed plants	50	260.8	95.5	237	93.0	338	88.6	287	99.3	287	107	53.6	86.6
Effect of treatment (−decrease, + increase in transpiration)		−12.1 ± 6.4		−16.6 ± 8.1		−43.2 ±21.9		−0.7 ±8.5					

In September whitening produces no effect, during the second fortnight of September it even somewhat increases transpiration. The transpiration coefficients, calculated for 1 g of raw substance (we were unfortunately unable to find out

the content of dry substance in the material) have shown whitened plants to spend by 13.6 per cent water less than controls.

Measurements of 5-minute long transpiration in severed leaves of plants from the field experiment showed that the loss of water by whitened leaves was by more than 20 per cent lower as compared to the controls (Table 2).

Table 2

Water Loss by Severed Leaves of Sugar-Beet in Field Experiment

Experimental set	Date	Hour of measurement	Loss by weight of leaves within 5 min.		Water loss by leaves reduced to dry air condition
			in g per 100 g of raw substance	in %	
Control	12.VIII	from 9 to 12	12.54±1.19	100	84.40
Whitewashing			12.49±1.05	99.6	81.13
Control	14.VIII	from 15 to 18	7.69±0.59	100	83.58
Whitewashing			6.32±0.79	82.2	80.86
Control	19.VIII	from 9 to 12	8.92±0.45	100	83.33
Whitewashing			7.99±0.43	89.5	81.33
Control	1.IX	from 15 to 18	11.18±0.50	100	82.13
Whitewashing			9.28±0.79	83.0	80.41
Control	2.IX	from 15 to 18	12.33±0.75	100	83.62
Whitewashing			10.34±0.57	83.8	80.54
Control	3.IX	from 15 to 18	12.05±0.48	100	83.95
Increased PK ration. Control			10.94±0.40	90.8	83.38
Increased PK ration. Whitewashing			9.45±0.50	78.4	83.63

Wilting and drooping was appreciably less pronounced in whitened leaves. The number of leaves per pot with plants kept at 80 per cent of total moisture capacity proved greater when whitened: on the average, 23.7 leaves on whitened plants as compared to 21.3 on controls.

The yield of sugar-beet roots in the pot experiment was found to be increased by the treatment by 13—14 per cent (Table 3).

Table 3

Yield of Sugar-Beet in the Pot Experiment of 1942

Exper. set	Humidity of soil in pots in % to total moisture capacity	Weight of root		Weight of green parts		Total weight of plant	
		g	%	g	%	g	%
Control	80	167±9.5	100.0	106	100.0	273	100.0
Whitened	80	190±7.9	113.7	115	108.5	305	111.7
Control	50	141±5.2	100.0	84.1	100.0	225	100.0
Whitened	50	159±5.7	112.7	91.7	109.0	251	111.1

No effect of whitening upon the crop of industrial beet could be observed in the field experiments. A. Okanenko in his tests carried out in the Kirghiz SSR in 1942, found that treatment with lime increases the yield of roots in sugar-beet by 5 per cent, and with bordeau-liquid, by 7.3 per cent, as compared to control. The yield of sugar is correspondingly increased by 5.2—6.6 centners per hectare.

Results of Experiments with Plants Left to Run Seed. The planting of roots was started on April 18, 1942. Whitening was prac-

tised during flowering, on June 30 and July 14; 1942. When collecting the crop, the total weight of a plant and the weight of the seeds were recorded separately for each group of each replication. Table 4 contains the results of the records for separate groups of roots (the arithmetical mean from 3 replications in each group).

The crop of the seeds was recalculated for 100 plants and the error of the arithmetical means determined for all groups. The figure obtained is 14.99 ± 0.59 kg for the control and 18.18 ± 0.57 kg for the whitened plants. Consequently, the difference between the weight of seeds from whitened and unwhitened plants is fully significant.

Table 4

Total Yield of Plants and of Sugar-Beet Seeds (in kg)

Nos. of group	Number of plants within the group	Unwhitened plants		Whitened plants			
		Total weight of plant in kg	Weight of seeds in kg	Total weight of plants		Weight of seeds	
				kg	% to control	kg	% to control
1	32	9.72	4.37	10.57	109	4.63	109
2	36	12.26	5.61	12.58	103	6.24	112
3	36	10.44	4.71	13.88	133	6.38	136
4	28	9.11	4.39	10.91	120	5.48	124
5	28	8.25	4.09	9.14	111	4.69	115
6	16	5.27	2.59	6.48	123	3.19	123
7	12	3.60	1.79	5.14	142	2.37	132
Total . . .		58.67	27.55	68.70	—	32.98	—

As may be seen from Table 4, the whitewashing of plants left to run seed results in a considerably increased weight of the seeds and of the plant as a whole. On the average this increase makes up 19.7 per cent for the seeds; and 17.1 per cent to the total yield of the plants. Recalculated to one hectare, it makes up 5.73 centners of additional seeds against a yield of 29.14 centners per hectare in the control.

The seeds obtained were tested for their germinating power and energy of growth. The results of the tests (Table 5) show that germinating capacity is not affected by whitening. But the energy of growth of the seeds obtained from whitewashed plants is considerably higher and the number of shoots greater than with the control seeds.

Consequently, the whitewashing of plants with lime has a beneficial effect not only on the yield of seeds, but on their quality, as well.

Table 5

Data on Energy of Growth and Germinating Power of Sugar-Beet Seeds

Exper. set	Exper. started on	Number of germinated seeds and shoots emerged									
		28.IX		29.IX		30.IX		2.X		5.X	
		seeds	shoots	seeds	shoots	seeds	shoots	seeds	shoots	seeds	shoots
Control . . .	25.IX	8	11	52	80	80	116	92	157	93	164
Whitened . . .		17	28	88	130	93	154	98	188	98	205
Control . . .	26.IX	1	1	11	16	69	109	90	158	94	178
Whitened . . .		1	1	23	39	80	122	94	176	95	184
Control . . .	28.IX	—	—	—	—	1	1	84	150	94	172
Whitened . . .		—	—	—	—	3	4	91	171	98	203

Conclusions

1. Under the conditions of the Kirghiz SSR, in order to improve water-regime in sugar-beet, it is advisable to whiten the plants with lime. This procedure reduces transpiration by 14—23 per cent.

2. Whitewashing of sugar-beet plants left to run seed at the period of flowering increases the yield of seed and improves the quality of the latter. Under the conditions of our experiment the yield of seeds in the case of whitewashing was found to be increased by 19.7 per cent.

In the experimental part of this work the author was aided by T. N. Belskaya and V. I. Tkachenko, technical assistants. The work was carried out under the guidance of Prof. E. V. Bobko.

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ECOLOGY

NUTRITIONAL VALUE OF PROTEINS IN THE GROWTH OF *CALLIPHORA ERYTHROCEPHALA* MG. *(DIPTEPA, INSECTA)*

By I. W. KOZHANTSHIKOV

(Communicated by L. A. Orbeli, Member of the Academy, 20. IV. 1943)

The specific adaptation of digestion processes in insects to the assimilation of definite proteins is beyond any doubt. The phenomenon is, however, highly complicated by the great diversity of nutritional conditions in different groups of insects.

No physiological characteristic of these conditions in different insect groups and of the processes of specialization to the protein nutrition is so far possible for lack of an adequate knowledge of these problems (1, 2).

The importance of proteins of the detritus in the nutrition of saprophagous insects has not been evaluated at all. There exist but a few transitory notes as to the specific relations of blow-flies to proteins. The study of the specialized protein nutrition of saprophagous insects is of great importance not only from the theoretical point of view, but also because of the utilization of blow-fly larvae in surgical practice. The most efficient dipterous species must be those which are the best specialized in feeding on detritus of tissues of higher animals.

In our experiments on *Calliphora erythrocephala* that served as material for this work, the larvae were bred on bits of fresh flesh of different animals, open to the influence of bacteria and other micro-organisms. Newly hatched larvae were placed in small glass containers on flesh without soil; after the second moult they were transferred into larger jars (20 cm in diameter) with flesh placed on the soil surface.

The soil served for the movement and pupation of larvae. All the experiments were carried out in an incubator at 20° C in darkness. The synchronism of different experimental runs guaranteed their maximum uniformity, in particular that of the composition of microflora.

The influence of the nutrition of larvae, in particular of its chemical constitution, is expressed in *Calliphora erythrocephala* in a different regree of mortality, in different intensity of their growth; and in different weight (dimensions) of mature larvae (pupae). The nutrition of the larvae with pure protein-albumin from egg, blood peptone and casein gives a slow growth; larvae do not attain maturity; although they live for a long time and moult once or twice, but they all die before pupation. A diet of pure aminoacids—alanin, glycocol, asparagic acid or aminovalerianic acid—is insufficient for larval growth; on such a diet all of them die at the first stage.

Calliphora larvae make a more or less complete growth only if fed on proteins of muscles of different vertebrates. Figures of Tables 1 and 2 make evident the

different nutritional value of proteins of different animals. Feeding on insect flesh proved possible only when flesh of *Calliphora erythrocephala* itself was used; and all larvae of the species studied died in the first stage, when fed on *Antheraea pernyi* flesh.

The best diet is beef-flesh; but it is impossible to extend this observation to all animals; since the feeding of *Calliphora* larvae, say; on dog-flesh increased their mortality and feeding on pig-flesh or flesh of rabbit resulted in the death of all of them. Judging by the rate of mortality, goose-flesh represents an adequate diet; but the figures of Table 2 point to a greatly retarded development of the larvae fed on this diet; in some cases (at 18.5°C) it lasts almost four times longer than under the same conditions on beef-flesh diet. Feeding on goose-flesh also protracts the processes of pupation and causes abnormalities in the pupae.

From among lower vertebrates frog-flesh shows high nutritive qualities for *Calliphora* larvae; it should be noted only a somewhat increased mortality among them, although the intensity of growth remains the same as under optimal conditions. Fish-flesh; on the contrary (*Gadus*, *Cyprinus*), shows much lower qualities, which is evidenced by a much increased mortality of the larvae and a decreased weight of the individuals. The feeding of *Calliphora* larvae on insect-flesh, even on that of the same species; which seems to be the only possible, has a very bad effect, judging by the same indices.

Table 1

Weight of Pupae and Mortality in *Calliphora erythrocephala* Mg. larvae Fed on Different Diet (at 20° C)

Diet	Number of individuals	% of mortality	Weight of pupae
Bos taurus	240	0	62.6 (90—18)
Canis domestica	200	11	54.4 (58—50)
Anser domesticus	240	1	—
Rana temporaria	300	1)	62.8 (31—34)
Cyprinus carpio	240	17	53.2 (76—26)
Gadus morrua	240	19	—
Calliphora erythrocephala	240	40	48.9 (66—37)
Antheraea pernyi	240	100	—

Table 2

Duration of Development of *Calliphora erythrocephala* Larvae Fed on Different Diet

Diet	Duration of development in days at					
	25° C	20° C	18.5° C	16.5° C	14° C	11° C
Bos taurus	8.4	11.8	13.9	29.1	44.1	63.1
Anser domesticus	7.6	19.7	44.5	75.6	85.1	90.0
Rana temporaria	8.4	11.3	16.0	34.2	61.1	68.0
Cyprinus carpio	7.7	11.6	15.8	33.1	47.7	61.3
Gadus morrua	10.0	12.6	15.5	21.3	55.6	57.8
C. erythrocephala	8.6	11.1	22.0	28.5	39.0	48.0
Antheraea pernyi	all perish at the first stage					

The above said characterizes *Calliphora erythrocephala* as a species specialized on larval nutrition on tissues of higher vertebrates; namely on mammals; probably, *Ungulata*.

The last is not clear and stands in need for some special experiments. *Calliphora erythrocephala* can be juxtaposed to *Ducilia sericata*, the larvae of which thrift equally on detritus of mammals or fish-tissues. The insufficient growth of the species studied on a diet of pure proteins or of separate aminoacids distin-

guishes this species from *Blatta* [3] or *Drosophila* [4]. In the former case (*Blatta*) the possibility has been shown of their growth on gelatine diet, in the latter (*Drosophila*), on a diet of pure and single aminoacids (alanin; glutamic acid). The larvae of *Calliphora erythrocephala* are much more specialized on protein compounds of food as compared with *Anthrenus* species; for the growth of the latter was observed on pure protein, a diet which consists of a few aminoacids [5].

In concluding it should be mentioned that *Calliphora erythrocephala*; being a species specialized on nutrition on proteins of higher vertebrates (warm-blooded), is of great interest as a material for surgical purposes. The larvae of *Calliphora* are purely detritophagous; their growth is accompanied by permanent alkaline reaction of substratum caused by intensive ammonia evolution. The intestine of *Calliphora* larvae shows highly developed bactericidal properties. The detritus where they live is usually inhabited only by a few species of saprophytic bacteria.

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HELMINTHOLOGY

ON THE EFFICIENCY OF CUTANEOUS INFECTION WITH HOOKWORM LARVAE

By G. G. SMIRNOV

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One of the most essential factors of percutaneous invasion by *Ancylostoma* larvae is the rate of invagination of the infective larvae into cutaneous coverings. There exist no special investigations devoted to this subject. Only in a few of the experimental works on the biology of *Ancylostoma* larvae one may run across brief and rather transitory remarks as to the number of larvae penetrating the skin within a definite period of time ([1–5]).

Smirnov and Kamalov (1940) ([6]) found that one hour after a hamster 22-day-old had been infected with larvae of *Necator americanus*, 30 per cent of the larvae failed to penetrate through the skin and remained on its surface. However, the recording of the number of larvae penetrating through the skin *in vivo* is a rather complicated procedure, and the results obtained lack necessary precision. We have therefore carried out a series of experiments *in vitro*, although an experimental model is necessarily conventional.

Ancylostoma larvae not older than 10 days were taken for the experiments. In one run (culture A) the culture contained larvae of *Ancylostoma duodenale* alone. The remaining two runs were carried on on mixed cultures: *A. duodenale* + *Necator americanus*. From treatment data the ratio *Ancylostoma/Necator* has been found to be 1 : 200 in culture B, whereas in the second culture C it proved to be 1 : 10.

The experimental set-up was a rather simple one. Four entomological test-tubes (12×2 cm) filled with water to the brim were placed in an electric water bath containing water at 40° C. Each tube was covered with a small piece of skin of a hamster (*Mesocricetus brandti*) stripped off from the abdominal part of a freshly killed animal. The skin thickness was practically the same, being taken from hamsters of equal age (60.0—70.0 g). The skin was stretched and fixed by means of a rubber ring so as to touch at the water surface of the tube. After being counted active infective larvae of man hookworms were transferred on the skin with the aid of a pipette.

After a definite period of time (15, 30, 45, 60 minutes) the larvae that remained on the skin, as well as those which had penetrated through the skin into the water, were counted under the microscope.

The experiment was carried out in July, at the Laboratory of the Tbilissi Tropical Institute*, Department of Helminthology. During day-time the temperature in the laboratory rooms fluctuated within 28—34° C.

* In these experiments we were kindly assisted by N. G. Kamalov to whom our thanks are due.

The experiment consisted of 6 runs; each of them involved 4 simultaneous test which lasted from 15 to 60 minutes.

Duration of exper. in min.	Number of larvae set on the skin	Out of them			
		Penetrated the skin		Passed through the skin	
		Number	%	Number	%
15	552	270	49	4	1.5
30	578	334	58	30	9
45	485	353	72	46	13
60	533	463	87	92	20

From the experimental data it is obvious that the maximum per cent of larvae (84) became invaginated into the skin and penetrated into the water in the first experimental run within one hour, irrespective of the duration of the test. In the other 20 experiments only 63 per cent were found invaginated into the skin. If the number of larvae that penetrated the skin in the run I be compared to that for the other runs, the following indices will be obtained (in per cent):

Duration of exper. in min.	15	30	45	60
Run I	64	94	79	94
Runs II-VI	46	48	72	86

Such a high activity of the larvae of the first run should evidently be accounted for by the properties of the culture of the larvae which belonged to the species *A. duodenale*. We became aware of the latter circumstance not until the treatment of the patients; the test with the corresponding culture could therefore not be repeated.

In the course of the first 15 minutes about a half of the total number of larvae migrated into the skin, whereas only isolated *Ancylostoma* larvae passed through the skin. As the duration of tests was increased, the skin was gradually penetrated by larger numbers of larvae (see table). The number of larvae in water showed, however, appreciable increase only in the first run. Out of the total number of larvae invaginated, only 12 per cent were found to have passed into water. It should be noted that almost in all experiments, except the run I, the number of larvae in water was also insignificant.

The following table gives respective data for each test duration of run I and the other series separately, which illustrate the penetration of larvae into water (in per cent):

Duration of exper. in min.	15	30	45	60
Run I	7	20	62	64
Runs II-VI	0	8	4	9

Practically, the larvae have been found to have migrated through the skin within the first thirty minutes of the experiment only. It should be supposed that the subsequent migration of larvae was impeded by alterations that took place in the isolated piece of skin.

What is the way to account for the important variation in the rate of invagination of the larvae into the skin? The most essential part in the invagination process of *Ancylostoma* larvae belongs to positive thigmotaxis; according to Lane ([7]); thermotaxis plays but a subordinate role. Chandler ([8]) points out that the larvae penetrate the skin only provided that they are covered with a thin water film, creating a support necessary for them to invaginate into the skin coverings. This conclusion is based on the work by Payne ([9]). She studied, however, the mechanism of migration of larvae in soil, and we see no reason to extend her data to percutaneous invasion.

In our tests the amount of water upon the surface of the skin was considerably reduced on account of evaporation only during those tests which lasted up to 60 minutes.

At the initial phase of the experiments, at 15-minute duration, the relative volume of liquid did not prevent the larvae from migrating into skin. Payne ([3]) who observed the behaviour of *Ancylostoma* larvae in water, points to the alternation of active and passive periods in them. The latter may fluctuate from several seconds to 30 min. The temporary passive state is inherent both in young and old larvae; irrespective of the contact with the substratum (thigmotaxis) and favourable temperature conditions (thermotaxis). The varying rate of penetration of the larvae into the skin may be explained by physiological differences in their activity.

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